ECONOMIC BIOLOGY

PHILIPPA C. ESDAILE

PART I

HARMFUL & USEFUL ANIMALS

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ECONOMIC BIOLOGY

ECONOMIC BIOLOGY

FOR

STUDENTS OF SOCIAL SCIENCE

BY

PHILIPPA C. ESDAILE, D.Sc. (Manchester)

READER IN BIOLOGY IN THE UNIVERSITY OF LONDON
KING'S COLLEGE FOR WOMEN, HOUSEHOLD AND SOCIAL SCIENCE DEPT.

PART I

HARMFUL AND USEFUL ANIMALS

WITH 150 ILLUSTRATIONS SPECIALLY PREPARED
BY THE AUTHOR

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TO

MY MOTHER

PREFACE

The prefaces to many text-books for the use of students begin with an apology by the writer for having added yet another book to the already long list on that particular subject ; but he generally points out how *his* book fills a special want or amplifies an aspect which he thinks has been but lightly stressed hitherto. In this case the position is different, for, so far as I am aware, there is no text-book on Economic Biology for students of Social Science. Butler's " Household Insects " covers only a section of the subject, that indicated in the title. Those who may be teaching Biology to students of Household and Social Science, of whom there are an increasing number, are faced with the difficulty of scattered literature and the host of disadvantages that are included in that condition, and it is to try to help these that this book is put forward. The word " text-book " has not been used in the title because it makes no claim to be one. It is really a kind of Materia Domestica, a collection of facts concerning certain animals and plants which are, or may be, closely associated with man and his household. However, a limit must be drawn somewhere, or else the work could only be accommodated in twenty rather than in two parts. So certain arbitrary restrictions have been made and much ground left untouched. This may be criticised, but a perusal of the Tables of Contents of the two parts indicates that the field covered is indeed a wide one and that the critic is even more ambitious than myself. Part I deals with " Harmful and Useful Animals," and Part II with " Animal and Vegetable Products."

The book was begun when I had the great advantage of the help and advice of the late Professor Arthur Dendy, F.R.S., and I wish to place on record my grateful thanks for his kind encouragement in the early stages of preparation.

With regard to the figures, many are original camera lucida drawings from specimens bred in my laboratory, while many are redrawn or based upon diagrams and figures in various papers and books, the original source being given in each case. I wish to acknowledge my obligation to all these authors, and in particular to Mr. Clifford Dobell, F.R.S. I am indebted to Messrs. Macmillan and Co. for permission to reproduce Figs. 31 and 33, and to *Country Life* for Fig. 118. Dr. A. L. Greaves and Professor Boulenger, M.A., kindly lent me the slides represented in Figs. 22 and 46 respectively.

My thanks are also due to Miss Triffitt, M.Sc., for the drawings of the Malarial Parasites (in Part I), and for help with that section, and to Miss Boxall, who contributed to the section dealing with Moulds (in Part II). Beyond this I have the satisfaction of knowing that I have not ensnared any collaborator to share with me any criticism the book may call forth.

London, 1927.

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STUDENTS OF SOCIAL SCIENCE

PART I

CHAPTER I

PHYLUM PROTOZOA

In the writings of Aristotle (384–322 B.C.) there is mention of at least 500 animals. Many of these he described at great length, giving considerable anatomical detail and observations concerning their life-history and feeding habits. These records are among the most remarkable in the world's history—not only are they the foundation of the great study of living things, but they provide a memorial of one of the greatest "giants of learning," the Father of the Study of Life-lore.

Aristotle dealt with the larger animals; not that he did not describe certain organisms of exceeding smallness, but he and workers for many centuries were unaware of the presence of those multitudes of "little creatures" which are now classed as the Protozoa. For it was not until 1681 that Antony van Leeuwenhoek, another "giant," discovered the flagellate *Giardia intestinalis* (a Protozoon found in the intestine of man), and thereby became the "Father of Protozoology."

Any text-book on Zoology—and the reader is recommended to turn to one of these for further information—will state that the Animal Kingdom is divided into two great divisions, the Protozoa and the Metazoa. The term "Protozoa" was first used in 1820 to define the animals

of primitive or archaic type, and the sub-kingdom Protozoa is now known to be one of the largest and most important groups of organisms. The Protozoa are minute, but yet exhibit a great diversity of structure, of life-history, and of habitat. The one feature they have in common is that they are what is generally known as " unicellular," i.e. the body-mass is of one cell. As already stated, these " unicellular " animals show an infinite variety of body form, and this is accomplished by a specialisation of this or that part of the cell. To give an example of this : the outermost part of the protoplasmic body-mass is the ectoplasm—this is nearest to and in most intimate relation with the environment, and is responsible for the production of organs of locomotion and various protective devices ; while the innermost part or endoplasm, relieved from the functions concerned with locomotion and protection, is responsible for the nutrition and reproduction of the individual. An examination of several Protozoons will further demonstrate this specialisation ; for example, in *Paramœcium* the ectoplasm develops special organs of locomotion, the cilia, special organs of offence and defence, the trichocysts, and a special organ for the intake of food, the cytostome.

The classification of the Protozoa is based mainly upon the differing types of organs of " locomotion."

Class 1. Sarcodina, with pseudopodia or temporary extensions of the ectoplasm forming organs of locomotion at any part of the body-mass. Includes free-living and parasitic forms.

Class 2. Mastigophora, with flagella or whip-like structures of a more or less permanent nature. Includes free-living and parasitic forms.

Class 3. Sporozoa, no organs of locomotion, but mostly producing sporozoites during the developmental stages. All parasitic.

Class 4. Infusoria, with many cilia or hair-like ectoplasmic filaments of a more or less permanent nature. Includes free-living and parasitic forms.

For the purpose of the present study two genera only

are selected for detailed consideration, *Entamœba* and *Plasmodium*. In the Preface it is stated that only a limited number of types is discussed here, and in this case these two genera are selected not because of their overwhelming importance medically, or because they are specially typical of their families, or because they are found among patients in the hospitals in this country, but because those interested in sanitation and in Household and Social Science ought to be ready, whether in this country or abroad, to assist in the prevention of amœbic dysentery and malarial fever. This can be done by seeing that the particular institution or household under their care is not assisting the propagation of these diseases, providing perhaps a breeding-ground by the neglect of sanitation and by the presence of conditions suitable for the spread and breeding of these organisms. In the case of the malarial fever-carrying mosquitoes, it is the duty of the individual as well as the Borough or County Council to assist in lessening their numbers.

Class 1. Sarcodina

Entamœba Casagrandi and Barbagallo

The genus *Entamœba* is one of the Class Sarcodina, a Protozoon possessing pseudopodia. There are three species found in man, but only one of these, *E. histolytica*, is pathogenic. *E. gingivalis* and *E. coli* are considered as harmless commensals.

Entamœba gingivalis (Gros) Brumpt. was the first Amœba found in man, described by Gros in 1849 in the human mouth in the tartar of the teeth. Sometimes it is abundant in the pus of pyorrhœal pockets. Some have claimed that it is the causative organism of pyorrhœa alveolaris, but several workers have negatived this suggestion and it is now considered as an "inoffensive commensal." It may even prove to be a useful, though somewhat ineffectual, scavenger of the mouth, feeding on bacteria and broken-down elements of the food of the host. The average size of *E. gingivalis* is 10–20 μ, though

some are described as measuring 25–30 μ. The ectoplasm and endoplasm are " fairly sharply differentiated and the pseudopodia are well developed, lobose, and typically rounded—not pointed." There are many food-vacuoles, most probably containing bacteria and debris of the mouth. There are no contractile vacuoles. The nucleus is spherical and eccentrically placed and only to be seen clearly in stained specimens. Reproduction takes place, most probably by binary fission. There is reason to believe that cysts are not formed by this species and that dissemination takes place in the unencysted state.

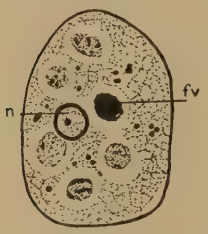


FIG. 1.—*Entamœba gingivalis.* × 1650. *f.v.* Food - vacuole, *n.* nucleus. (After Dobell.)

Entamœba coli (Grassi) Casagrandi and Barbagallo was discovered by Lewis in 1870 in the course of cholera investigations conducted in India with Cunningham as collaborator. The " amœbæ " were found in 18 per cent. of the stools of cholera patients, but it is now established that *Entamœba coli* is found also in the stools of healthy people and that it is not the causative organism of amœbic dysentery. It is also a harmless commensal, and is found in the colon of man, where it may act as a useful scavenger in the same way as *E. gingivalis* in the human mouth.

FIG. 2.—*Entamœba coli.* × 1650. *n.* Nucleus. (After Dobell.)

E. coli is much larger than *E. gingivalis* and exhibits great variations in size ; 18–40 μ are the limits mentioned by some writers, but the average, according to Dobell, is 20–30 μ. The unencysted form is sluggish, and there

is no active motion as in *E. histolytica*. There is no marked difference between the ectoplasm and the coarsely granular endoplasm. The numerous food-vacuoles in the endoplasm contain bacteria and vegetable debris, and sometimes the cysts of pathogenic Protozoons present in the colon of man, but red blood-corpuscles and tissue elements of the host are not ingested. There are no contractile vacuoles. The nucleus is conspicuous and eccentric in position. There is no record of this species occurring elsewhere than in the colon of man. It is probable that binary fission takes place. Encystment is preceded by a general contraction of the body-mass and the disappearance of the food-vacuoles. After the cyst is formed, the nucleus divides until eight nuclei are formed. The cysts are passed out with the fæces, and should these be exposed to the air and dried to a certain extent (complete desiccation kills the contents of the cyst), dissemination is brought about by the wind. They measure 15–18 μ in diameter. The powers of resistance to adverse circumstances are considerable. The cyst-wall breaks down in the alimentary canal of man, causing the liberation of eight small amœbulæ.

FIG. 3.—*Entamœba coli*. Eight-nucleate cyst. × 1650. (After Dobell.)

Entamœba histolytica Schaudinn (emend. Walker) was discovered by Lösch (1875) in the stools of a patient suffering from relapsing dysentery in Russia. The active amœboid forms found in the intestines of man measure about 20–30 μ in diameter. Dobell compares its appearance when extended and in motion to that of "a slug moving at express speed." The ectoplasm is clear, while the colourless finely granular endoplasm has many large food-vacuoles containing red blood-corpuscles and tissue elements of the host. The nucleus is inconspicuous until stained and, compared with *E. coli*, the peripheral chromatic layer is delicate. It is eccentric and measures 4–7 μ in diameter.

As already stated, the food of this pathogenic form is

the blood-corpuscles and tissue elements of the host. The amœbæ, liberated in the large bowel from the cysts taken in by the patient, attack the gut walls, probably secreting a powerful ferment which has a histolysing effect upon the cells of the gut, thus causing a breaking up of the tissues and liberation of the blood-corpuscles of the host and rendering possible their ingestion by the amœbæ, and giving the amœbæ entrance to the blood-vessels, by means of which they are carried to the lungs and other organs. The portions of the intestines attacked in this way develop large ulcers. By simple binary fission the amœbæ rapidly increase in number, and penetrating into the gut linings they cause the ulcers to become deeper and larger. Hæmorrhage, toxic action, and a general lessening of the efficiency of the gut lining bring about the symptoms characteristic of amœbic dysentery.

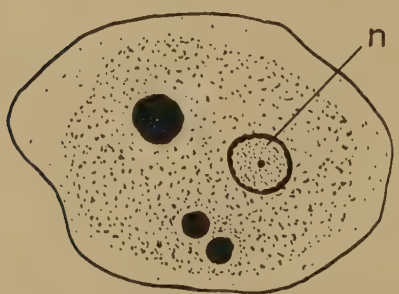
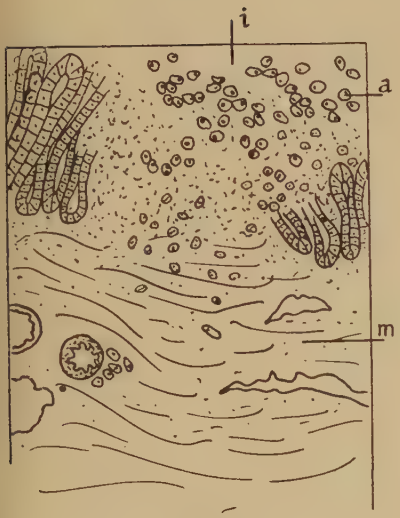


FIG. 4.—*Entamœba histolytica.* The causative organism of amœbic dysentery. × 1650. *n.* Nucleus. (After Dobell.)

After a time certain of the amœbæ pass from the ulcers into the large intestine, where they encyst, closing the food-vacuoles and contracting in size. The ovoid quadrinucleate cysts, measuring 7–15 μ, are passed out with the fæces. Many active amœbæ are discharged also, but these never encyst and, having no power of resistance, quickly die.

In many cases symptoms of amœbic dysentery are not produced, even though *E. histolytica* is present in millions, the reason for this being that the host is able to tolerate the presence of the amœbæ but not to destroy them. "The host and parasite are in a state of equilibrium," a condition which is best suited to the normal growth of the Protozoon. For Dobell has emphasised that the pathological conditions caused during the illness of the host are upsetting to the parasite as well as to the man. These "carriers," as they



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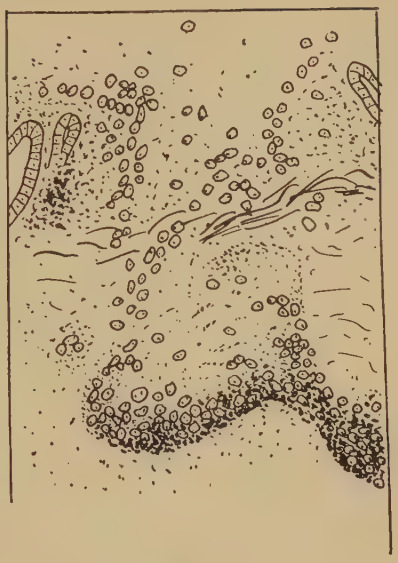

Fig. 6.

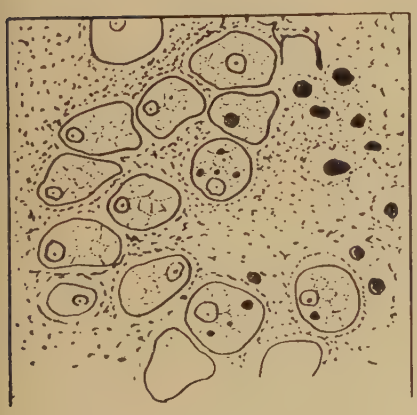

Fig. 7.

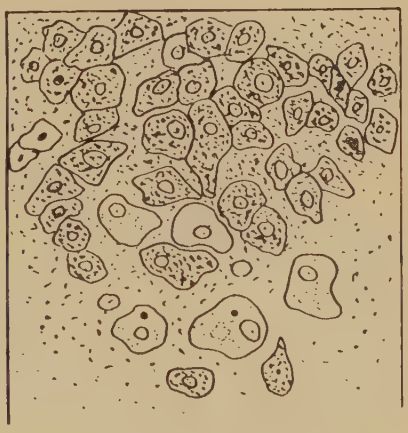

Fig. 8.

SECTIONS ILLUSTRATING ENTAMŒBA HISTOLYTICA IN THE TISSUES.

FIG. 5.—Section of an early intestinal ulcer. × 70. *a.* Amœba, *i.* intestine, *m.* muscular wall of intestine.

FIG. 6.—Section of a deep-seated ulcer in the wall of the intestine. × 70.

FIG. 7.—Enlarged view of *Entamœba histolytica.* × 450.

FIG. 8.—*Entamœba histolytica* in the liver. × 450. (All after Dobell.)

are called, are most dangerous people, as, unaware of the guests they harbour, due precautions are not taken against the almost inevitable dissemination of the cysts.

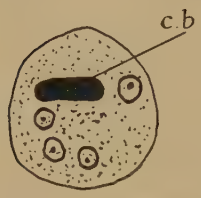

FIG. 9.—*Entamœba histolytica.* Quadrinucleate cyst. × 1650. *c.b.* Chromatoid body. (After Dobell.)

Enough has been said to indicate the care that is necessary in the disposal of excretory matter of a patient, and especially of a "carrier," for it is the latter that discharges more numerous and healthy cysts. An outbreak of dysentery must not only mean the treating of the patients, but a diligent search and subsequent treatment of the unsuspecting "carrier," who is probably the cause of all the trouble. Though most prevalent in the tropics, amœbic dysentery or amœbiasis is common in temperate zones; in fact it has been stated that 10 per cent. of the inhabitants of the globe are infected.

Class Sporozoa

Genus Plasmodium (the Malarial Parasite)

Volumes and whole sections of innumerable volumes deal with this subject in great detail, making it unnecessary to give here more than an outline account of this organism and its connection with man.

The disease malarial fever (miasm or paludism) has been known for centuries and was always associated with the mists and vapours in the neighbourhood of marshy country, hence the origin of its name. In 1847 Haeckel, while conducting post-mortem examinations on malaria victims, observed pigment in certain of the tissues. This he considered to be connected with the disease. In 1880 Alphonse Laveran, a surgeon of the French Army, described the presence in the blood of patients of "parasitic elements," which he stated were "probably the principal cause of the manifestations of paludism." This aroused much controversy at first, but later verifications proved that Laveran's statement was correct. Golgi carried the work

further and described different types of malarial parasites. But it was Ross (1898) who discovered and worked out the life-cycle, finally demonstrating that the organisms attacking the red blood-corpuscles of man were but a phase in a complicated life-story that was completed in the body of the mosquito.

It was shown that the three types of fever, benign tertian, quartan, and æstivo-autumnal or malignant, were associated with the presence of the three types of parasites now known as *Plasmodium vivax* Grassi & Feletti, *P. malariæ* Laveran, and *P. falciparum* Welch. Catanei and Grassi and others suggest that these are not valid species, but are only " transitory morphological adaptations of the typical forms." This is not the place for discussion on so important a point, and for simplicity's sake the causative organisms will be named as above.

In each case the infected malaria-carrying mosquito brings the infection to man, and, depending upon the power of the man to withstand the attack, the virulence of the parasites, and the number transferred, the periods of incubation are respectively 14–18 days, 18–21 days, and 9–12 days.

Certain people, though carrying malarial parasites in their blood, never develop pathological conditions and act as " carriers." Unless medically treated, the blood of these people, if sucked by a mosquito, may be the means of spreading the disease. The particular stage that is transferred to man is the sporozoite (see Table I and Figs. 10, 11, and 12); this attacks a red blood-corpuscle, penetrates within it, and then proceeds to grow at its expense, passing thereby into the trophozoite stage. The trophozoite then becomes a schizont or merocyte, and eventually its nucleus divides and the parasite fragments into a number of small nucleated masses or merozoites. These are liberated into the blood flow by the breaking down of the cell wall of the blood-corpuscle, and at the same time certain toxins, collected in the blood-corpuscle by its foreign occupant, are set free. This has a disastrous effect upon the host and causes the symptoms

characteristic of the particular type of malarial fever. Some of these merozoites proceed to attack other red blood-corpuscles, and so complete the asexual or schizogonic or human cycle ; others develop into gametocytes

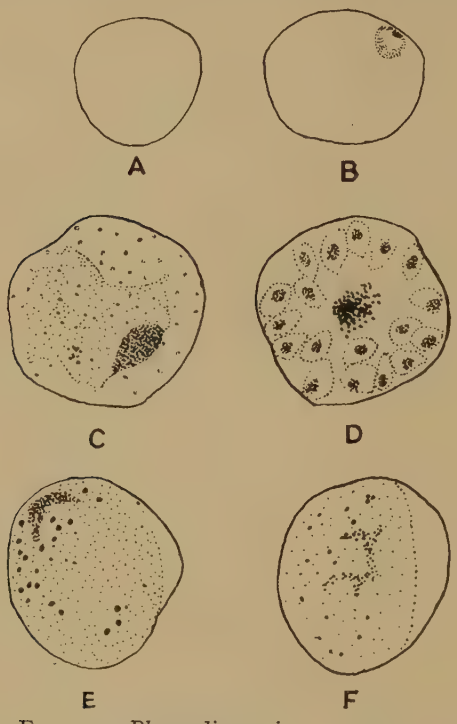

FIG. 10.—*Plasmodium vivax*. × 2200.

(Camera lucida drawings by Miss M. J. Triffitt, M.Sc.)

A. Red blood-corpuscle, uninfected and normal in size.
B. Young trophozoite—ring form in red blood-corpuscle.
C. Schizont in enlarged blood-corpuscle.
D. Sporulation—the schizont dividing to form merozoites.
E. Macrogamete.
F. Microgamete.

and give rise to macrogametes (female gametes) or microgametes (male gametes). These cannot proceed with their development unless transferred to a malaria-carrying mosquito. It is well known that the females of many mosquitoes have become blood-sucking, while the males, less well provided with piercing mouth parts, live on fruit

juices. Fortunately, in the case of many of these insects the gametocytes are digested as part of the meal of blood ; but Ross demonstrated that the female mosquito of certain species of certain genera is incapable of digesting these particular cells, which are able, not only to withstand the digestive process of the Invertebrate host, but find them-

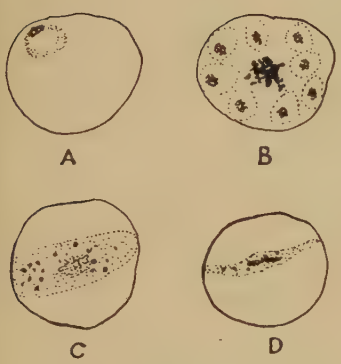

FIG. 11.—*Plasmodium malariæ.* × 2200.

(Camera lucida drawings by Miss M. J. Triffitt, M.Sc.)

A. Ring form.
B. Sporulation to form merozoites.
C. Macrogamete.
D. Microgamete.

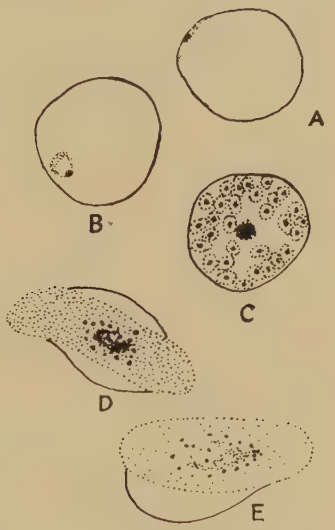

FIG. 12.—*Plasmodium falciparum.* × 2200.

(Camera lucida drawings by Miss M. J. Triffitt, M.Sc.)

A. Young trophozoite.
B. Ring form.
C. Sporulation (from a spleen smear).
D. Macrogamete.
E. Microgamete.

selves in the environment suitable for the completion of the sexual or sporogonic cycle or " cycle of Ross." These mosquitoes have already been referred to as " the malaria-carrying mosquitoes," and it is to these females of certain species only that the spread of malarial fever is due.

The asexual cycle is continued in man until remedies kill the parasites or until they wear themselves out, the liberation of merozoites causing the accession of fever

symptoms at the regularly recurring intervals characteristic of the particular malarial type.

The sexual cycle is therefore necessary for the continuance of the parasite. In the stomach of the mosquito the large macrogamete develops and awaits the coming

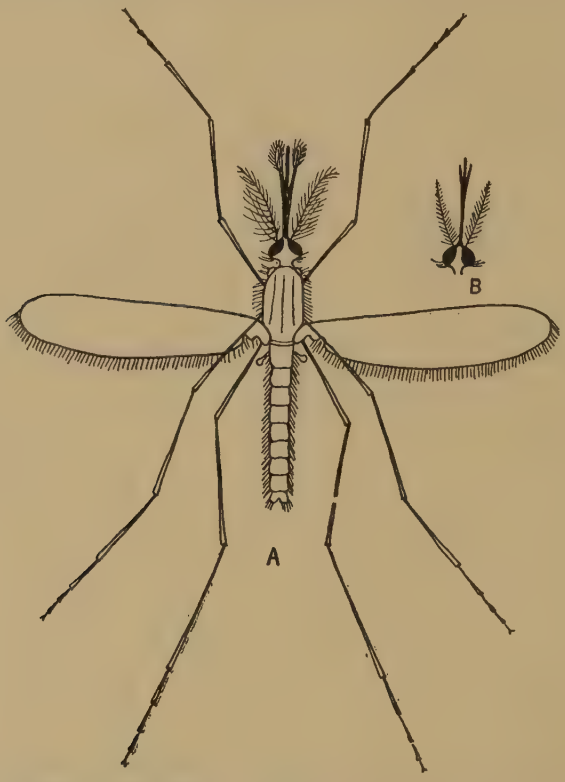

FIG. 13.—*Anopheles maculipennis.* One of the malaria-carrying mosquitoes. × 5. (After Austen.)
A. Male. *B*. Head of female.

of the microgamete. Conjugation takes place and the zygote is formed. The zygote then leaves the stomach by penetrating through the wall, and there on the outside of the stomach wall and inside the peritoneal lining the zygote develops to form a plasmodial cyst, its contents fragmenting to form innumerable sporozoites. These cysts may be present in great numbers. After a time the

cyst wall breaks down and the sporozoites make their way into the salivary glands. The mosquito taking a meal of blood punctures the skin of man, and pours saliva

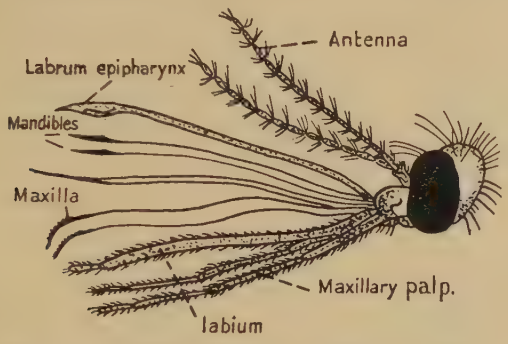

FIG. 14*a*.—Mouth-parts of female *Anopheles*.
(After Nuttall and Shipley.)

into the wound to prevent coagulation of the human blood in its stomach. The wound therefore becomes infected by the saliva containing the sporozoites, and the sporozoites, thus finding access to the blood-stream, are quickly carried along away from the wound where they entered,

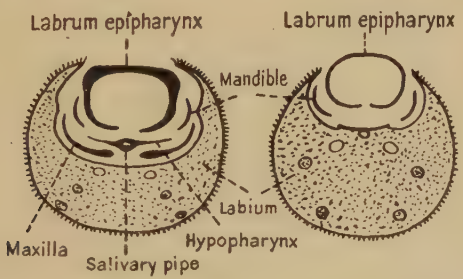

FIG. 14*b*.—Diagrams of transverse sections of the mouth-parts of *Anopheles*.
Left, female. *Right*, male.
(After Nuttall and Shipley.)

soon to give rise to the trophozoites. A mosquito when once infected is most probably capable of transmitting malaria for the rest of its life.

The following table indicates the main differences between the three types of malarial parasites and the fevers they cause.

TABLE I

Type of Fever.	Benign Tertian Fever.	Quartan Ague.	Æstivo-autumnal or Malignant Malaria or Pernicious Malaria.
Causative organism .	*Plasmodium vivax* . .	*Plasmodium malariæ* . .	*Plasmodium falciparum.*
App. incubation period .	14–18 days . . .	18–21 days . . .	9–12 days.
Trophozoites . .	Large; develop "signet ring" 2 μ in diameter; blood-corpuscle enlarges; Schüffner's dots formed; parasite actively amœboid, hence name.	"Signet ring" formed; blood-corpuscles do not enlarge; no Schüffner's dots; parasite sluggish.	"Signet ring" thin and small; blood-corpuscles do not enlarge; fairly active.
Schizogony . . .	Every 48 hours, i.e. accession of fever on 1st, 3rd, 5th, 7th, etc., days.	Every 72 hours, i.e. accession of fever on 1st, 4th, 7th, 10th, etc., days.	At irregular intervals.
Merozoites . . .	16–24 in number; 8·5–10 μ in diameter.	6–12 in number.	15–32 in number; 4·5 μ in diameter.
Gametocytes . .	Rounded; enlargement of corpuscles. ♂. 9–11 μ; does not fill corpuscle; nucleus large. ♀. 10–14 μ; fills corpuscle; nucleus small, dense.	No enlargement of corpuscle; otherwise resembles those of *P. vivax*.	"Crescents" appear in peripheral blood 10 days after infection; may circulate in peripheral blood for 5 days, cause blood-corpuscles to cling to walls of blood-vessels and so obstruct circulation. "Crescents" 9–14 μ long, 2–3 μ broad. ♂. Gametocyte (pigment distributed) gives rise to many microgametes; these correspond in function to spermatozoa of higher animals. ♀. Gametocyte (pigment concentrated round nucleus) gives rise to one macrogamete.

It is clear that the malaria-carrying mosquitoes are of the very greatest importance to man and that their extermination must be accomplished before mankind can be rid of malarial fever. Imms gives the following list of the more important carriers of one or more forms of malaria: *Anopheles maculipennis* (Europe, parts of U.S.); *A. culicifacies* (India); *A. costalis* and *A. funestus* (Africa); *A. albimanus* (Central and S. America); *A. quadrimaculatus* (U.S.). The Anophelines are members of the Order Diptera. The eggs are deposited singly in water, one individual laying 40–100 eggs, each one with its pair of air-floats. The larvæ, hatching out quite quickly, are aquatic and capable of existing in the smallest puddle of water. The Anopheline larva rests parallel to the surface of the water and the non-malarial mosquito hangs from

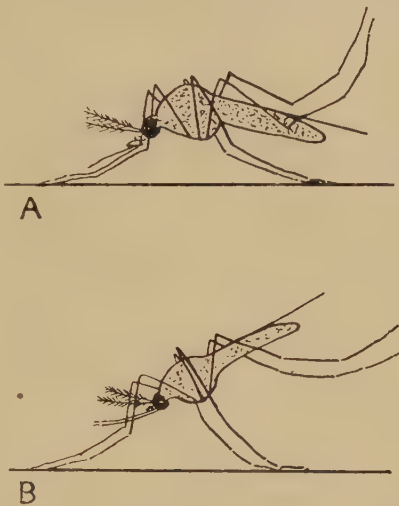

FIG. 15.—Diagrams showing the resting positions of,

A. Anopheles, a malaria-carrying mosquito.

B. Culex, a non-malaria-carrying mosquito.

(After Edwards.)

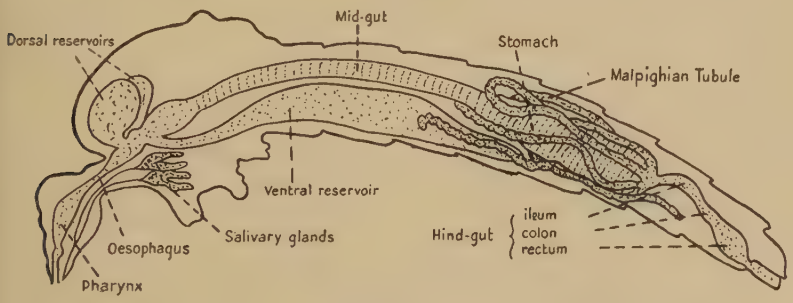

FIG. 16.—Diagram of the alimentary canal of the mosquito. (After Herms.)

the surface head downwards. The pupæ are also aquatic, and both breathe by means of syphons thrust into the air through the surface film. The adult insect emerges from the pupal case, and when its wings are hardened it begins its aerial life. The mosquito is most vulnerable in the aquatic phases, and efforts are made to prevent the adult from finding water in which to lay its eggs, either by careful drainage, the doing away of the possibility of standing pools and puddles, or by

FIG. 17.—Egg of *Anopheles maculipennis*, dorsal view. (Magnified.) (After Nuttall and Shipley.)

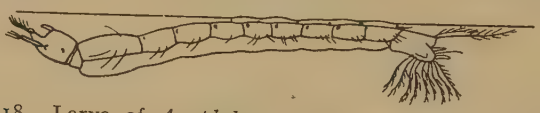

FIG. 18.—Larva of *Anopheles maculipennis*. (Much enlarged.) (After Howard.)

the covering of water-butts and tubs, and the treatment of water that *must* be exposed, with oil, in such a manner that the larvæ and pupæ cannot live.

In a malarial country each householder owes it to his fellow-creatures that puddles, pools, and ornamental water, often so decorative to a garden, shall be prohibited, and that all water-butts shall be covered, or else he may be responsible for the death of his neighbours.

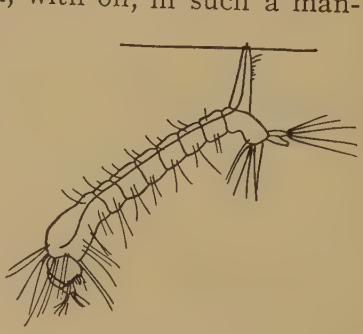

FIG. 19.—Larva of *Culex* suspended from the surface of the water, in distinction to the malaria-carrying mosquito whose characteristic position is parallel to the surface of the water. (Much enlarged.) (After Carpenter after Howard.)

England may consider herself fortunate that she is not a "malarial" country," for in many counties the malaria-carrying mosquitoes are present in great abundance. Luckily they are uninfected. Malaria was endemic in England in the Thames Valley during the early part of

the nineteenth century, but it was stamped out and has not reappeared. During the Great War there was considerable probability of another outbreak due to the movement of troops from infected countries to regions in Great Britain where the Anopheline mosquito occurs. This was averted by the investigation of all mosquito breeding-grounds and the registration of all regions infested with Anophelines. Thus by the restricted movement of infected troops the disease was kept under control and not permitted to spread to either the civil or military population. It is worthy of note that, owing to neglect of similar precautions, malaria was in 1923–4 sweeping through Russia. The natives had collected firewood from marshy ground infested with Anopheles, and the subsequent

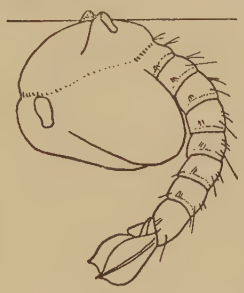

FIG. 20.—Pupa of *Anopheles maculipennis*. (Much enlarged. (After Nuttall and Shipley.)

FIG. 21.—Diagram representing the life-history of *Plasmodium falciparum*. The stages in the blood of man are placed below the line.

storing of it in their houses brought out the hibernating insects, which fed on infected and uninfected persons.

Konokhov, working in Russia, made and confirmed the following important observation. Certain mattresses infected with *Cimex lectularius* and *Pediculus humanus corporis* were placed in the sun for disinfectant purposes. The former occupants of the beds were malarial patients and the ectoparasites were still gorged with their last meal of blood, which contained many specimens of *Plasmodium falciparum*. Konokhov proved that mosquitoes attacked the bugs and lice, and, puncturing the abdomen between the chitinous plates, they obtained a meal of human blood in a second-hand manner and so became infected with malarial parasites. Transmission experiments are being conducted to show whether or not *P. falciparum* loses its virulence during the passage through the bug or louse. If the transmission of malaria can be effected in this way, yet another difficulty is added to the problem of its control.

Readers should refer to detailed accounts of the best methods of keeping mosquitoes out of houses by suitable screening and netting, and of the correct use of quinine as an important safeguard for man against malarial parasites should it be likely that they might be transferred to him.

The struggle against malaria has assumed an even greater importance since the publication of the Report on the Researches on Blackwater Fever. In his conclusions Thomson states that the disease is due to the repeated attacks of *Plasmodium falciparum*. He finds no evidence that any other specific organism is the causal factor, and believes that blackwater fever would be stamped out if the hygienic measures necessary for the prevention of malaria were used.

SCHIZOMYCETES

Spironema pallidum Vuillemin, 1905

Syphilis is perhaps the most dreaded of human diseases. It is placed third or fourth on the list of

so-called killing diseases, and is responsible for a very great deal of the troubles and difficulties in ill-health amongst most human races. The very nature of the disease adds to its terror, for the slow, insidious period of incubation sometimes lasts for months, increasing in intensity, gaining a complete hold of the system before the trouble declares itself. The distribution of syphilis is universal, bringing in its train insanity, paralysis, still-birth, and barrenness. It is fundamentally a venereal disease, transmitted in the majority of cases by impure sexual intercourse. The syphilitic patient cannot, however, always be looked upon as one who has lived an immoral life, for unfortunately there are many thousands of cases where syphilis has been contracted innocently by contact with insanitary barbers, uncleanly dentists, and by the eating of unwashed fruit and vegetables which have been contaminated by porters and salesmen, and by the use of infected drinking-cups, etc. Sadder still is the fact that doctors, nurses, and midwives may contract the disease from their patients.

Historians state that syphilis was unknown in Europe before the year 1493, when it was introduced by the crew of Columbus after his first voyage to the island of Española or Haiti, where the majority of the crew became infected and returned sick to Spain. But there is almost undoubted evidence that that famous knight of old, John of Gaunt, died in 1399 of syphilis, and some doubt is cast upon the cause of death of Henry IV—it was said to be leprosy, but the symptoms were more characteristically syphilitic. After the arrival of Columbus in Barcelona, syphilis spread rapidly amongst the inhabitants. In 1494 Charles VIII of France conducted a military campaign against Italy, using mercenaries from many other countries, including Spain. Thus the French Army became infected, and the disease spread rapidly throughout Italy, where it was known as "French disease." During the later course of the disease in the Old World each country called it after the country from which it received it; thus it became known also as "Portuguese disease," "Polish disease,"

etc. It is certain, however, that in America syphilis had been known from time immemorial, and at the coming of Columbus the Indians " were already in possession of a highly complicated, yet rationally deduced method of cure."

The causative organism is a spirochæte, *Spironema pallidum*. Spirochætes have at different times been classified amongst the Protozoa, and again amongst the Bacteria ; but a recent suggestion is that they should be classed by themselves as the Schizomycetes. They are minute, spirally coiled thread-like organisms. They differ from the Protozoa in the absence of a distinct nucleus, the chromatin matter being diffused throughout the elongated cell. The Schizomycetes reproduce by transverse binary fission ; in addition to this, according to Fantham, some genera reproduce by the formation of coccoid bodies, that is, numerous minute rounded particles, resulting from the breaking up of the original cell. *Spironema pallidum* measures 7–14 μ in length, and its thread-like body is wound into 6–14 regular, sharp coils. It progresses actively with a wave-like motion and with a corkscrew rotation of the body. When the full 14 μ is reached, the organism breaks into two halves, consisting of seven perfectly regular coils, each 1 μ in length. The organism contaminates a new host through some abrasion of the body, often a wound on the lip, and the first stage of the disease is that of the multiplication of the parasite in the lesion and lymph-glands. It then passes into the blood, multiplying as it does so, and making its way eventually into the cerebro-spinal fluid and reaching every tissue of the body. The earlier lesions may pass unnoticed and the presence of the parasite may not make

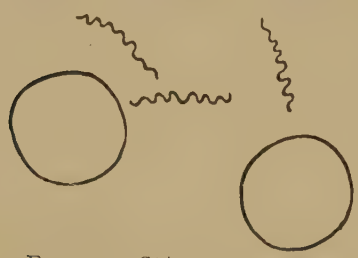

FIG. 22.—*Spironema pallidum*. Camera lucida drawing of the parasites and two red blood-corpuscles. (From a slide prepared by Dr. A. L. Greaves, of the Bacteriological Dept. of the London Hospital.)

itself known until later in the life of the patient. Syphilis is now diagnosible except in the earliest stages by means of either the " Wassermann " or the " luetin " tests, and if treatment be begun very early, there seems little doubt that a complete cure can be effected.

Control.—The discovery which revolutionised the treatment of syphilis was that the organism is unable to exist in the presence of arsenic and mercury salts, arsenic having the greater effect. The poisonous nature of arsenic, however, rendered its use difficult until the production of salvarsan, an organic, arsenical substance, first prepared by Ehrlich. A later improvement has led to the use of neo-salvarsan, and this is frequently followed by a course of salts of mercury. The prevention of syphilis is a wide and much-discussed subject, and scarcely within the scope of this book. The three main lines of attack are : (1) the abolishing of prostitution ; (2) the avoidance, when possible, of exposure to syphilis, or precautions to be adopted by doctors, nurses, and midwives whose work may lead them into contact with infection ; (3) the actual combating of the disease.

CHAPTER II

PHYLUM PORIFERA

Passing now from the Protozoa to the Metazoa, we find organisms consisting of many cell-units—in other words, the multicellular animals. At the outset of this study it should be pointed out that within the Metazoa there are two groups, the Parazoa (Sollas) and the Enterozoa (Ray Lankester).

The Parazoa is a small group created to include and separate the Phylum Porifera or Sponges from all other multicellular animals. A general definition of the Metazoa has been given as follows : " Multicellular organisms in which the cell-units are differentiated into at least two groups (ectoderm and endoderm) having contrasted properties and functions instead of being equiformal and interchangeable in function as in the multicellular Protozoa."

Embryological research has demonstrated the impossibility of homologising the cell-groupings in the Parazoa with the ectoderm, endoderm, and mesoderm of the two-layered and three-layered Metazoa. Any discussion of this question is outside the scope of this book, but the fact is stated in order that the reason for the separation of the Porifera from the Enterozoa (or rest of the Metazoa) may be understood.

The Phylum Porifera, therefore, occupies an isolated position at the base of the Metazoa. It includes a vast number of organisms all consisting of many cells. The majority are marine, a few are fresh-water, but all are aquatic. Some are solitary, while most form colonies, built up by a repeated process of budding, causing a heaping of one individual upon another and resulting in the formation of an amorphous mass of living matter. The word " sponge," familiar to us all as applied to a particular

substance used when washing, is there reduced to its narrowest meaning. The zoologist uses it as a general term for *any* member of this large Phylum Porifera. The commercial product, " sponge," is the dead skeletal matter obtained from a few species of the smallest class of the Phylum Porifera.

The ancestral Poriferan was in all probability solitary, and the description of the complicated colonial bath-sponge will, therefore, be prefaced by a brief account of the general body-structure of a simple sponge, such as *Sycon, Grantia,* or *Leucosolenia.* The organism may be compared to a minute thin-walled sac attached to some support, a fixed rock or a floating piece of seaweed. The external surface of the sac is pierced by countless openings, the inhalent pores, perforations of the so-called pore-cells or prosopyles. Sea-water, in which are many microscopic floating organisms, is drawn in through these pores by the action of " collared cells " lining minute cavities in the thickness of the body-wall. These collared cavities are connected with the great central cavity of the sac, and the water, now deprived of oxygen and organic matter used for food, leaves the organism by a large exhalent opening or osculum, situated at the end of the sac opposite to the point of attachment. The cells lining the canal system, and those forming the general body-mass and body-covering, are specialised for their respective functions, but, as said before, cannot be homologised with the " germinal layers " of the Metazoa. Thus, there are the flat pavement-cells covering the external body-surface, the prosopyles or porocytes, the collared cells which line the flagellated chambers of the canal system, while between these are many kinds of connective-tissue elements, contractile cells or muscular cells, amœbocytes, archæocytes, or undifferentiated amœboid cells which may give rise to ova in females and spermatozoa in males or may remain as amœbocytes,

FIG. 23.—Diagram of " collared " cells of the bath-sponge.

and also there are cells responsible for the growth of the skeleton.

The majority of the Porifera possess a skeleton. This is in the form of often beautifully modelled spicules of very definite shape and often arranged in a very characteristic manner; in some this is calcareous, in others it is silicious, while in the small class Euceratosa, with which we are specially concerned, there is no calcareous or silicious skeleton, but a system of horny fibres ramifying throughout the colony and giving support to the whole structure. These horny fibres are deposited by cells known as spongoblasts and the fibres themselves are composed of a substance known as spongin.

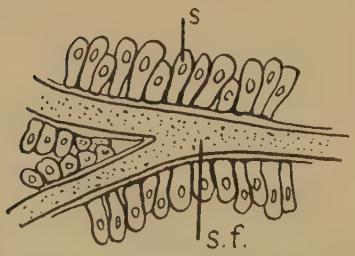

FIG. 24.—Diagram of a spongin fibre of a bath-sponge surrounded by spongoblasts. *s.* Spongoblast, *s.f.* spongin fibre. (From a slide lent by Professor Dendy.)

The Euceratosa, like the majority of the Porifera, are colonial, i.e. the individual resulting from the development of the fertilised egg-cell gives rise by budding to many daughter individuals. These do not separate themselves from the parent, but remain attached and themselves form other individuals by budding. With the development of the colony the outline of the individual is lost, the canal systems of the individuals become linked up and, as already stated, a large amorphous mass is formed with outer inhalent pore-cells letting the sea-water into a complicated canal system. The water

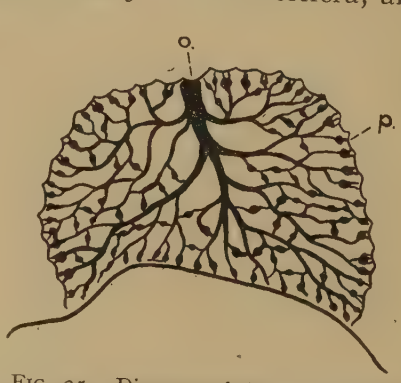

FIG. 25.—Diagram of the canal system of the bath-sponge. *o.* Osculum, *p.* pore-cell. (After Dendy after Schultz.)

then finds its way out of the sponge by the many oscula or exhalent openings, the number of oscula giving some indication of the number of individuals forming the colony. The two genera from which the commercial bath-sponge is obtained are *Euspongia* Brown and *Hippospongia* Schulze, the technical distinction being that in *Hippospongia* the canal system is supplemented by a series of wide canals and spaces.

The outline of the body is broken by many irregularities, and these little prominences or conuli are caused by the terminal primary branches of the spongin fibres (Fig. 26). The primary spongin fibres are connected by numerous secondary fibres (·035 mm. in diameter) and the skeleton forms a scaffold supporting the whole body. In certain places the spongoblasts may be seen surrounding the fibre they have secreted. The bath-sponge when growing is therefore of the same general form as the commercial product, but is brownish in colour and soft and slimy with the presence of the tissue elements. Frequently various bodies become entangled in sponges, and when these are in the nature of sand, stones, or the shells of Molluscs, the value of the commercial product is considerably diminished.

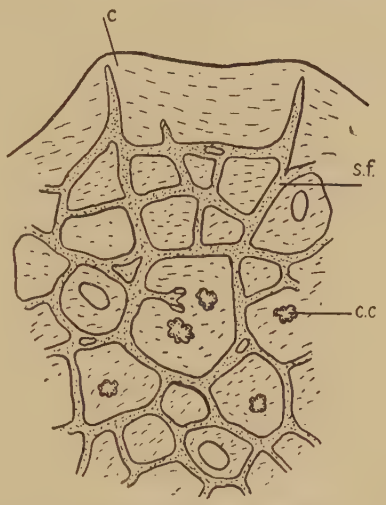

FIG. 26.—Diagrammatic section of the bath-sponge. *c.* Conulus, *c.c.* "collared chamber," *s.f.* spongin fibre. (After Dendy.)

The geographical distribution of *Euspongia* and *Hippospongia* is extensive, and, provided that the temperature and depth of the water and the nature of the floor of the sea are suitable, these genera may grow in many places.

However, it is not many localities which provide sponges of a sufficiently high quality to render their gathering a sound commercial venture. For instance, conditions might bring about such a great accumulation of foreign matters in the body of the sponge that it could not be removed even by the most vigorous and careful treatment, or the sponge growth might be scanty or productive only of sponges of unsuitable shapes.

The three localities where sponge fisheries are possible are in the comparatively shallow waters of the Mediterranean, the coasts of Florida, and the Bahama Islands, at a depth of about 21–80 fathoms. Both genera are found in all three localities. The following is a list of the more important species. The Mediterranean sponges are :

Euspongia officinalis var. **lamella.** The " Elephant-ear " sponge, " Lappet " sponge, or " Leather " sponge. The oscula are restricted to one surface. Cut into small pieces and used for French polishing.

Euspongia officinalis var. **mollissima.** The " Turkey " or " Lavantine " sponge. Many of these are cup-shaped. The outer fibres are very thin, with the result that these sponges are soft and fine.

Euspongia officinalis var. **adriatica** is also one of the " fine " sponges of the trade, often called the " honeycomb " sponge.

Euspongia zimocca is the " hard " brown " Turkey " sponge. Often cup-shaped. Used mostly for cleaning lithographic stones.

Hippospongia equina is the " Horse " sponge or common bath-sponge with a massive bun-like body.

From Florida and the Bahama Islands the following are obtained :

Hippospongia equina var. **gossypina.** The " Sheep's-wool " sponge is very abundant and valuable. Much used.

Hippospongia equina var. **macandriniformis.** The " Velvet " sponge. This is not so common, and not so very useful as it is not as durable as the others.

Hippospongia graminea, Hippospongia cerebriformis.

" Grass " sponge ; given this name because of the length of the outer fibres.

Euspongia agaricina. The " Yellow " sponge. This resembles the " Zimocca " sponge of the Mediterranean. Those from the Bahama Islands are inferior to those from Florida.

Euspongia tubulifera. The least valuable ; rather loosely constituted.

The sponges are dragged up off the rocks either by a dredge or by divers armed with some sharp instrument. A rotting process is first necessary to cause the decay of the living matter, then the debris is washed away and the spongin skeleton freed as much as possible from all sand, shells, and other foreign bodies. After bleaching the sponges are dried, clipped, sorted, and packed for export.

Efforts are being made to increase the sponge-fisheries by a systematic protection of the sponge-beds to prevent an over-stripping of valuable areas. Also experiments have been carried out in connection with the planting of cuttings and the rearing of young sponges in protected areas or " nurseries." Sponge-fishery investigations have been continued in the British West Indies since 1920, and it is hoped that the sponges may become more plentiful.

The results of the " nurseries " have been successful. Cuttings of sponges, a cubic inch in size, which must include some of the outermost tissue, used to take about seven years to grow to a reasonable size for gathering, but with the new methods and the care of the sponge-beds this time has been considerably shortened.

CHAPTER III

PHYLUM PLATYHELMIA

The history of the nomenclature of the "worms" is a long one and not without interest. The great group of "Vermes," as it was called by Linnæus, has been divided and subdivided and rearranged in a variety of ways, too numerous to be recounted here. Modern zoologists, led by Lankester (1877), then discarded this too comprehensive term, and in its place several co-equal Phyla were created for the accommodation of the vast assemblage of greatly differing forms which Linnæus had gathered together. Vogt (1851) first used the word "Platyelmia," most appropriately, to include what he considered were flat-worms; but it was not till Bürger's time that the Phylum Platyelmia or Platyhelmia (a modification introduced by Lankester) consisted of only the flat-worms. Bürger removed the Nemertines, which Vogt had included.

Three widely differing Classes constitute the Phylum Platyhelmia, the Turbellaria, Trematoda, and Cestoda. Genera from the last two Classes only are discussed here, but in order to understand these parasitic forms it is necessary to consider something of the characters of the hypothetical ancestors, and the Class Turbellaria, a group of free-living organisms which certainly are more likely to retain ancestral characters than either of the other two Classes, including as they do parasitic and therefore highly modified types.

In Chapter II mention was made of the division of the Metazoa into two groups, the Parazoa and Enterozoa. Taking up the story there, even a superficial knowledge of the Enterozoa reveals the fact that they are conveniently divided into two. Firstly, the "Diblastica," containing one Phylum, the Cœlenterata (Hydra, Sea-anemone, etc.),

whose body-cells are differentiated into two groups, ectoderm and endoderm. These two layers of cells constitute a body-wall enclosing a general body-cavity or cœlenteron (corresponding in function to the two cavities of the higher types—cœlom and enteron) provided with one opening, which must serve as both entrance and exit.

Secondly, the "Triblastica," which include all the other animals. Here the body-cells are differentiated into three groups, the ectoderm, endoderm, *and* mesoderm, an intermediate mass of cells formed in between the

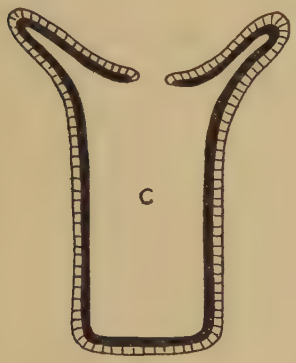

Fig. 27.

Fig. 28.

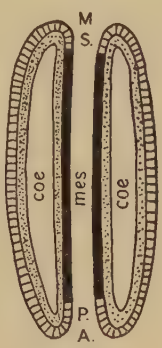

Fig. 29.

FIG. 27.—Diblastic type.
FIG. 28.—Acœlomate triblastic type.
FIG. 29.—Cœlomate triblastic type.
Hatched = ectoderm, black = endoderm, spotted = mesoderm.
A. Anus, *C*. cœlenteron, *coe*. cœlom, *M*. mouth, *mes*. mesenteron, *P*. proctodæum, *S*. stomodæum.

ectoderm and endoderm. In many of the triblastic types this mesoderm is a solid mass of cells without a cavity, so that the acœlomate Triblastica, though possessing three categories of cells, have only one body-cavity, that of the endoderm or digestive cavity, and an undivided mass of mesoderm. On the other hand, the cœlomate Triblastica, possessing a divided mesoderm, have two cavities, the cavity of the endoderm which lines the major part of the alimentary canal, and the cœlom or true body-cavity which is the cavity of the mesoderm and is lined by mesoderm.

The Platyhelmia are a group of acœlomate Triblastica.

The ancestor of the Platyhelmia was in all probability a small, oval, bilaterally symmetrical creature, flattened dorso-ventrally, propelling itself through the sea-water by means of the cilia of the ectoderm, aided by the movements of the mesodermal muscular cells which became arranged in circular and longitudinal bands. A delicate diffuse mesh-work of nerve fibres was present, lying underneath and derived from the ectoderm. At the anterior end some of these fibres grouped themselves and lay more closely, forming a collection of sensitive cells which constituted the beginnings of a brain. The cavity of the endoderm gave rise to the greater part of the gut, and the space between the body-wall and wall of the gut was crowded with mesodermal tissue, some specialised to form simple, tubular, hermaphrodite genital organs whose microscopic cavities, if there were any, were the first indications of the cœlom. An excretory system was then necessary to drain the comparatively thick mass of mesodermal tissue, and this ancestor probably possessed the earliest stages of the " flame-cell " system. In the Protozoa and Cœlenterata contractile vacuoles performed this function. The flame-cell excretory system may have been derived from this, the vacuole remaining permanently open and forming a cavity continuous with that of a long prolongation of the cell which merged with other hollow cells to form a mesh-work of delicate tubes. These persistent vacuoles received the waste matter in solution that was encouraged to enter from the surrounding tissue

Fig. 30.—Diagram of " flame cells." (After Borradaile.)

by the flickering movements of the cilia-like projections from the protoplasmic lining of the cell.

The Turbellaria retain many of the characters of their hypothetical ancestors. They are all free-living, many are marine, and to the zoologist they offer a fascinating study, whether taken from the anatomical, cytological, or physiological aspect.

Class Trematoda

This Class includes parasitic Platyhelmia and, with parasitism, many changes in structure and life-history are to be noted. The soft ciliated epidermis is replaced by a thick resistant chitinous cuticle which it secretes, and the epidermis itself sinks down and loses its identity in the mesoderm. Suckers are developed, and by their aid the parasite is enabled to retain its advantageous position on the outer surface of or in the cavities of its host.

Fasciola hepatica Linnæus, 1758

The liver-fluke is found in the liver and bile-ducts of the sheep, but it is recorded also as having been found in the mountain hare, fallow deer, roe deer, ox, goat, ass, and horse. Very rarely it occurs in man. It is considered one of the most serious epidemic diseases of sheep and cattle and its ravages may be very severe. The liver may be packed with flukes and its substance riddled with the cavities in which they live. The bile-ducts may be completely blocked. The disease is known as " liver-rot " or " staggers," the latter on account of the uncertain gait of its victims.

The adult fluke is flattened, about 30–35 mm. in length and about 10–20 mm. at the broadest part. The cuticle is very tough and possesses backwardly projecting chitinous spines. The mouth, surrounded by the oral sucker, is at the extreme anterior end. The genital opening is a little behind this on the ventral surface, while a little farther back still is the ventral or posterior sucker.

The mouth leads into a muscular sucking pharynx and the food is passed into the intestine ; this almost

immediately bifurcates and the two great branches pass backwards on either side of the body, giving off many diverticula. The excretory system consists of numerous

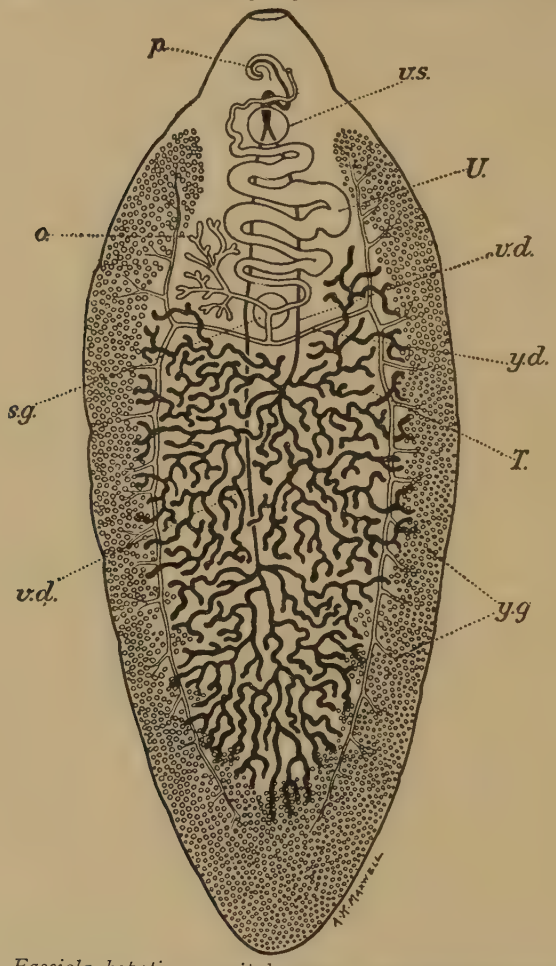

FIG. 31.—*Fasciola hepatica*—genital organs, seen from the ventral side. *O.* Ovary; *p.* penis; *v.s.* ventral sucker; *s.g.* shell-gland; *T.* testis; *U.* uterus; *v.d.* vas deferens; *y.d.* yolk-duct; *y.g.* yolk-glands. (From *Zoology for Medical Students*, by Graham Kerr, published by Macmillan, 1921.)

"flame-cells" and a mesh-work of connecting tubes opening to the exterior at the extreme posterior end. The nervous system is composed of a nerve-ring round the pharynx and two rather loosely constituted lateral nerve-

trunks. The organism is hermaphrodite ; the simple ancestral condition of the genital organs is highly elaborated and they are very large. An enormous number of eggs is necessary, for, as in all parasitic forms, the wastage is considerable. The female genitalia comprise a single ramified ovary, very extensive yolk-glands, a shell-gland,

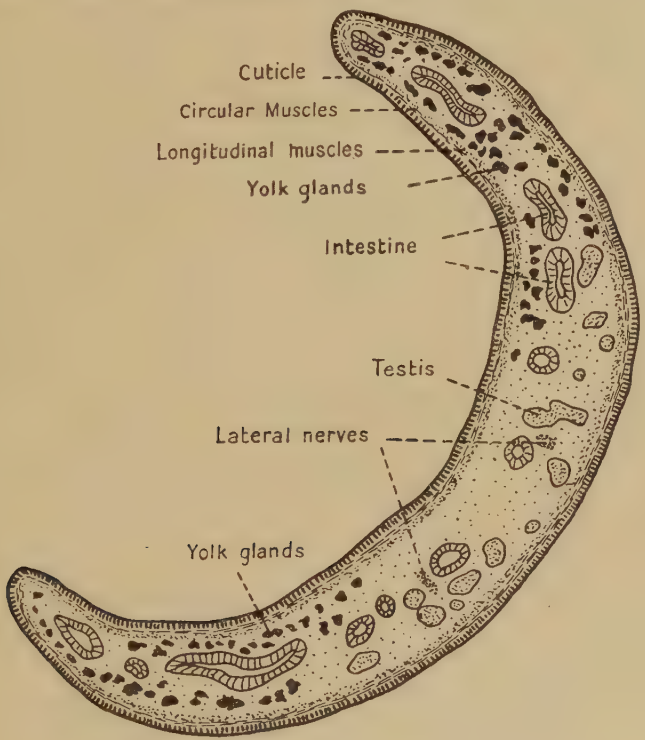

FIG. 32.—Transverse section of *Fasciola hepatica*. × about 2½.

and a uterus ; and the male genitalia, a pair of ramified testes, a pair of vasa deferentia, a seminal vesicle, and an ejaculatory duct terminating in a penis. It is probable that fertilisation is effected hypodermically, the penis making the puncture in some other fluke and the sperms finding their way through the tissues to the oviduct. In this way the ova passing from the ovary are fertilised, receive a store of yolk, are covered by a shell, and are

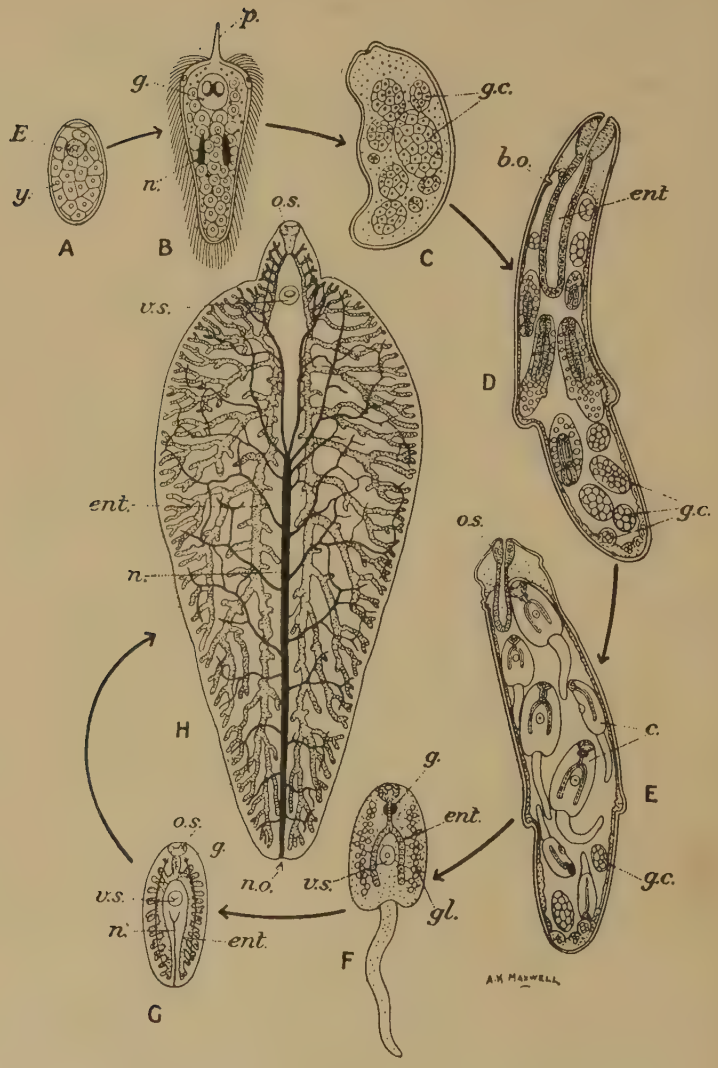

FIG. 33.—Life-history of *Fasciola hepatica*. A, "egg"; B, miracidium; C, sporocyst; D, E, rediæ; F, cercaria; G, tailless encysted stage; H, adult (neither reproductive organs nor nervous system are shown), *b.o.* reproductive opening of redia; *c.* cercaria; *E.* egg; *ent.* intestine; *g.* nerve-ganglion; *g.c.* germ-cells; *gl.* cyst-producing gland-cells; *n.* nephridium (only a few of the main branches of the excretory network are shown); *n.o.* nephridial opening; *o.s.* oral sucker; *p.* proboscis (extruded); *v.s.* ventral sucker; *y.* yolk-cells. (From *Zoology for Medical Students*, by Graham Kerr, published by Macmillan, 1921.)

later stored in the uterus before they finally leave the fluke. The eggs are passed out of the body of the sheep with the fæces and are dropped in the grass. Should the eggs be dropped on dry ground, nothing further happens; but should the grass hold drops of water or should the eggs reach a ditch, a minute ciliated miracidium larva (·12 mm. in length) will hatch out in a few weeks. For the continuance of the cycle it is necessary that the miracidium should come into contact with a certain amphibious snail, *Limnæa truncatula* Müller. When it does so it burrows into the snail by means of its proboscis and eventually travels to the large blood-spaces near the lung, where it changes into a bag-like structure, the sporocyst. The germ-cells of the sporocyst give rise to another developmental phase, the redia. The redia may give rise to other generations of rediæ (a phenomenon known as pædogenesis), and eventually to a cercaria. This is an actively swimming form, minute in size and tadpole-like in appearance, propelling its elongated body by the lashing movements of the tail. The cercaria swims about in the water or may get caught in a drop of water on a blade of grass, and the thirsty sheep coming towards the ditch, taking the damp grass or drinking the water, receives the cercaria into its alimentary canal. Here the cercaria develops into the adult fluke.

Fortunately in this country the regulations governing meat inspection guard the public from the sale of meat unfit for human consumption.

Class Cestoda

To this Class belong the flat-worms, more commonly known as the "Tape-worms," for not only are they flattened dorso-ventrally, but the majority possess segmented bodies and some, attaining a considerable length, closely resemble a piece of tape. These organisms are evidently very ancient parasites, for in every way they show a profound modification to their specialised mode of life, e.g. a very thick cuticular covering, an entire absence of alimentary canal, and no trace of sense-organs

in the adult. The life-cycle is in all cases complicated and two hosts are necessary for its completion. The tape-like form occurs in a vertebrate, while the phase known as the bladder-worm, found in the majority of Cestodes in a vertebrate host also, is in some cases present in an invertebrate host. That their presence as a harmful parasite of man is no new discovery is evidenced by reference to early writings. The Mosaic Law forbade the use of certain " unclean " beasts, and these included the rabbit, hare, and pig, all types which act as " intermediate " hosts for certain tape-worms. Some of the terminology used to this day had its origin in Syria and Greece. Solium = chains (Syrian). Hydatid = hailstones (Greek).

Aristotle described parasitic worms which he found in the guts of specimens he examined, and from his accounts it is clear that he had seen the Nematodes that lie freely in the alimentary canal and the Cestodes that are attached to the gut-lining by their suckers and hooks. The history of this subject will be touched upon later.

A general description of a tape-worm and its life-history is as follows :

In the strobila two parts may be distinguished, the *scolex*, or head, and the main part of the organism, which is frequently tape-like in structure. The scolex is the organ of attachment of the parasite to the wall of the intestines. Its anterior end is enlarged to bear the suckers and hooks, if any, and behind this is the " neck," which by budding gives rise to the chain of segments. The scolex contains the anterior nerve-ring, and from this pass the lateral nerves to the segments. As already mentioned, there are no sense-organs and no alimentary canal. The chain is divided into a number of segments or proglottides, and as these are budded off from the neck the oldest is the farthest from the scolex. The chain of proglottides is therefore a series of segments ever increasing in number, and each segment of the chain only differs from the others in the matter of age. As will be seen from Table II, the strobila may be many feet in length in some species, while microscopic in others. The

function of the strobila is to provide the vast number of eggs necessary in the case of a parasite. Each segment contains a complete set of hermaphrodite reproductive

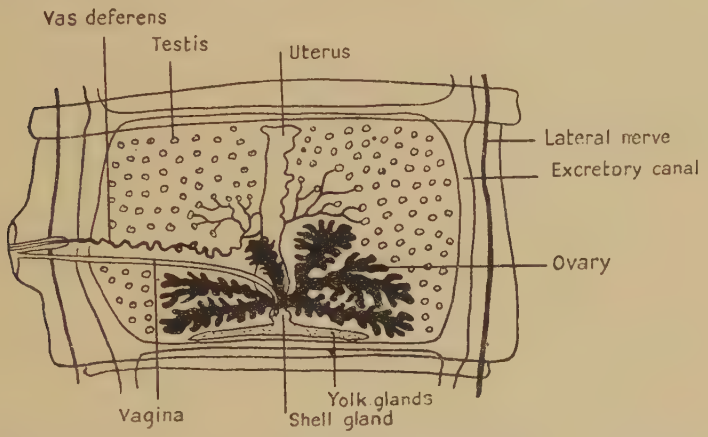

Fig. 34.—Diagram of a proglottis of *Tænia solium*. × about 8. (After Shipley from Cholodkowsky.)

organs, each capable of producing innumerable eggs. Figs. 34 and 35 illustrate the structure of a proglottis.

The general scheme of the reproductive organs shows

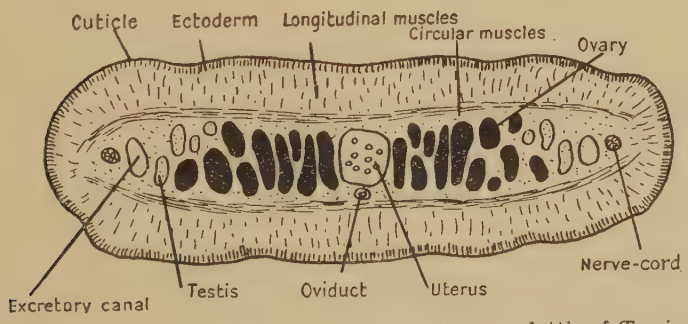

Fig. 35.—Transverse section through a mature proglottis of *Tænia*. × about 9. (After Shipley.)

some resemblance to that of *Fasciola hepatica* ; but in the tape-worms there is a vagina, and fertilisation is effected by the transfer of sperms to the vagina by the penis of a proglottis of the same or of some other worm. As the

eggs accumulate in the uterus, this structure enlarges and develops diverticula to accommodate them, so that a " ripe " proglottis is little more than a bag of eggs, all the other structures having disappeared and given place to the distended uterus. The excretory system is of the " flame-cell " type ; the position of the main ducts, longitudinal and transverse, may be seen in Figs. 34 and 35. The openings to the exterior are on the last segment.

The tape-worms are found, as already stated, in the intestines of the host attached firmly to the walls by the suckers and hooks which are controlled by powerful muscles. The parasites may be present in great numbers, even causing obstruction. When ripe, the posterior proglottides become detached from the chain, and short lengths, of perhaps 2–20 segments, are passed out with the fæces. By a subsequent decay of the body-wall of the proglottides the egg-cysts are liberated. If the fæces are exposed, the wind will blow them about and pigs, hares, rabbits, or cattle (i.e. intermediate host), will then take them into their alimentary canal with their food. These heavily shelled cysts can withstand the rigours of adverse circumstances, but the digestive juices of the intermediate host quickly dissolve the shell and a small larva is liberated. The hexacanth larva, so named because of its six minute hooks, proceeds to burrow through the wall of the alimentary canal and is eventually carried

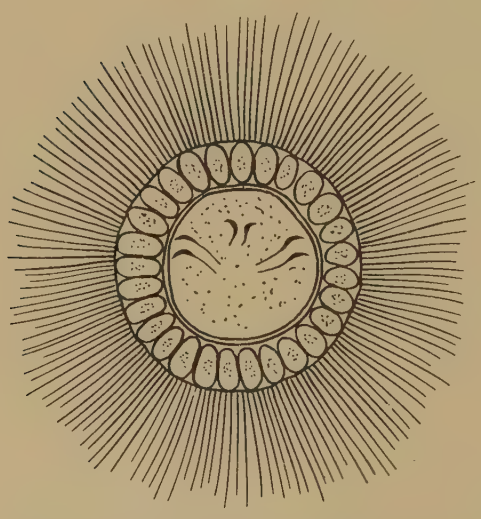

FIG. 36. — Free ciliated embryo of *Dibothriocephalus latus*. (Much magnified.) (After Castellani after Leuckart.)

by the blood-stream to the muscles or to some body-space, where it becomes lodged. Here the hooks disappear and the larva encysts and is called the bladder-worm.

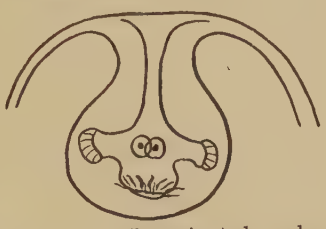

FIG. 37.—Invaginated scolex of *Tænia saginata*. (Much magnified.) (After Leuckart.)

In the case of some hosts the parasite seems to cause but little inconvenience, but in others, namely, *Echinococcus granulosus* in man, the cyst may be several inches in diameter, with a thick outer cuticle and inner endocyst containing fluid. Surrounding the whole thing is a thick connective-tissue coat formed by the host as the result of the irritation the parasite causes in the tissues. These large structures often cause great inconvenience and serious obstruction.

In the case of the rabbit and hare, these may be caught and eaten by a dog, or the infected and perhaps imperfectly cooked flesh of the pig or beast eaten by man. Then the cyst, reaching the alimentary canal, is liberated from the tissue in which it has been lodged and the action of the digestive juices breaks down the cyst-wall. In the meantime development has been taking place within the cyst, the scolex of the new tape-worm has been formed or, as in *Echinococcus granulosus*, there may be several heads in one bladder, the hydatid cysts of the Greeks. During encystment the scolex, in all cases, is inverted; but when the cyst-wall has broken down and the bladder-worm is free in the gut, the scolex becomes everted and ready to attach itself to the gut-wall. At first there is just the scolex and short neck with the remains of the bladder attached, but the bladder is soon reduced in size and by budding the chain of segments is formed.

FIG. 38.—Evaginated scolex of *Tænia sp.?* × about 10.

From the very earliest times these bladder-worms have been known and recognised as parasites. Redi (1687–1705) considered that they were adult animals and failed to recognise that they were only a phase in the life-history of the tape-worm, with which he was quite familiar. Zeder (1800) also held this view and erected the group Cystici for their inclusion. They were dignified by generic and specific terms, e.g. "*Cysticercus cellulosæ.*" Küchenmeister in 1851 finally proved, by feeding experiments, that the tape-worm and bladder-worm were different

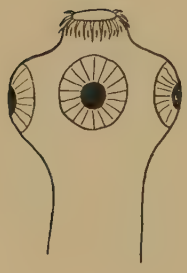

Fig. 39.

Fig. 40.

Fig. 41.

Fig. 42.

FIG. 39.—Diagram of the scolex of *Tænia solium.*
FIG. 40.—Diagram of the scolex of *Tænia saginata.* (After Leuckart.)
FIG. 41.—Diagram of *Echinococcus granulosus.* (After Leuckart.)
FIG. 42.—Diagram of the scolex of *Dibothriocephalus latus.* (After Leuckart.)

phases in the life-history of the same animal. But it would seem he was only providing a basis for the Law of Moses, whereby the Children of Israel were protected from the ravages of tape-worms.

Castellani lists and describes fully twenty-four species of Cestodes which are found in man. Particulars of the four most important species are given in the following table.

There are then many tape-worms that attack man and the name given to the diseases thus caused is Intestinal

TABLE II

—	*Tænia solium* Linn., 1758.	*Tænia saginata* Goeze, 1782.	*Echinococcus granulosus* Botsch, 1786. (*Tænia echinococcus*) Zeder, 1803.	*Dibothriocephalus latus* Linn., 1748.
Final host . . .	Man.	Man.	Dog.	Man, dog, cat.
Intermediate host . .	Pig, man, rarely sheep and dogs.	Ox; never found in man.	Ox, sheep, pig (and sometimes man).	Fresh-water fish.
App. length of Tape-worm	6–10 feet.	12–30 or more feet.	2·5 to 6 mm.	30 feet.
Scolex	22–30 well-developed hooks in 2 rows.	No hooks.	28–50 hooks in 2 rows.	No hooks.
	4 suckers. (See Fig. 39.)	4 large suckers. (See Fig. 40.)	4 suckers. (See Fig. 41.)	2 suckers slit-like in shape. (See Fig. 42.)
Neck	Long.	Long.	—	—
Proglottis . . .	800–900 in number.	1000 in number.	3–4 in number.	3000–4200 in number.
	10–12 mm. in length.	16–20 mm. in length.		Very broad.
Genital pore . . .	Lateral. Generally alternate.	Lateral. Irregularly alternate.	Lateral. Alternate.	With separate median opening.
Mature uterus . . .	7–10 lateral branches. (See Fig. 43.)	20–35 lateral branches. (See Fig. 44.)	Lateral protuberances, no true lateral branches. (See Fig. 41.)	Rosette-shaped. Median and ventral in position. (See Fig. 45.)
Eggs	31–38 μ diam.	Ovoid. 35–40 μ × 20–30 μ.	30–36 μ diam.	Ovoid. 68–71 μ × 45–50 μ.
Cysticercus . . .	"*Cysticercus cellulosæ*" in muscles.	"*Cysticercus bovis*" in muscles.	Hydatid cyst in muscles, liver, etc.	Cyst in muscles.

Tæniiasis. The following is the symptomatology given by Castellani :

" Gastric and reflex symptoms, mostly of a vague nature. The former comprise salivation, diarrhœa, and constipation, with colicky pains, nausea, vomiting or dyspepsia ; while the latter include faintness, unequal pupils, disorders of vision and hearing, headache, itching of the nose or anus, vertigo, epilepsy, etc. Anæmia and skin eruptions have also been recorded."

Test experiments have been made with " extract of

Fig. 43.

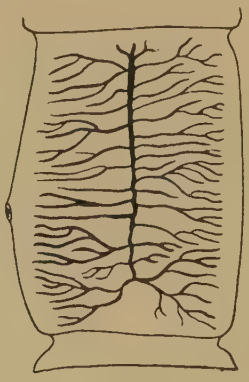

Fig. 44.

Fig. 45.

Fig. 43.—Proglottis of *Tænia solium.*
Fig. 44.—Proglottis of *Tænia saginata.*
Fig. 45.—Proglottis of *Dibothriocephalus latus.* (After Leuckart.)

tape-worm," and the injection of *Dibothriocephalus latus* and *Tænia solium* each produced toxic effects, while extract of *Echinococcus granulosus* caused peritonitis and severe cardiac symptoms. In the case of small animals a heavy dose resulted in death, preceded by a rapid fall of blood-pressure and temperature. The aim of the treatment is to get rid of the parasite. This is by no means easy, as the hooks and suckers give the scolex a firm hold, but it is clear that if the scolex, with its ever-budding neck, is not removed the evil is still there. The patient is first treated with purgatives and cleansing enemas in order that the extract of *Felix mas* (male fern), taken in the

form of capsules by mouth, may be as undiluted as possible and so quickly cause the relaxation of the muscles of the suckers and hooks. Further cleansing enemas are administered to wash away the loosened parasites.

With regard to the infection of man, all food should be carefully prepared and examined. The careful washing of salads and other things not generally cooked is essential. It is also well to remember that good and thorough cooking renders even infected food harmless.

CHAPTER IV

PHYLUM NEMATHELMIA

The Nemathelmia are acœlomate worms, elongated and tubular in shape, commonly called the "round-worms." The body is covered with a smooth cuticle which is often ringed. This is not an indication of segmentation, but merely an external wrinkling. Sometimes there are a few bristles, and more rarely, suckers. There is no blood vascular system or respiratory organs. In most cases the sexes are separate, but some few show a hermaphrodite condition. They are usually parasitic for at least a part of their life-cycle.

It is with only one Class that we are concerned, the Nematoda (Rudolphi, 1808), and this includes certain round-worms found in man or in some of his foods. They possess an alimentary canal but no proboscis. Throughout the Class, and indeed throughout the Phylum, there is remarkably little variation in body-structure and a general description of one species will suffice.

Family Ascaridæ (Baird, 1853)

Ascaris lumbricoides (Linn., 1758) is the causative organism of Ascariasis, a disease which may be dangerous if the parasites are present in great numbers. It is very common and is found all over the world. It may also attack the monkey, squirrel, dog, and pig. Found usually in the small bowel, it may wander into the stomach, œsophagus, mouth, nose, and bronchi, causing bronchial symptoms. It has more rarely been found in the liver, where it may cause abscesses, and appendicitis may be set up by its presence in that region. By its wanderings through the tissues it may cause perforation of the bowels and may make possible the migration of bacteria. As in all Nema-

todes, the female is larger than the male, measuring 200–400 mm. in length and 5 mm. at the greatest diameter, while the male measures 150–250 mm. × 3 mm. Both are yellow in colour with a reddish hue. The posterior end of the male is sharply recurved and provided with two small bristles. In both sexes, three small papillæ surround the mouth, one dorsal and two ventral. Within the leathery wrinkled skin is a syncytium

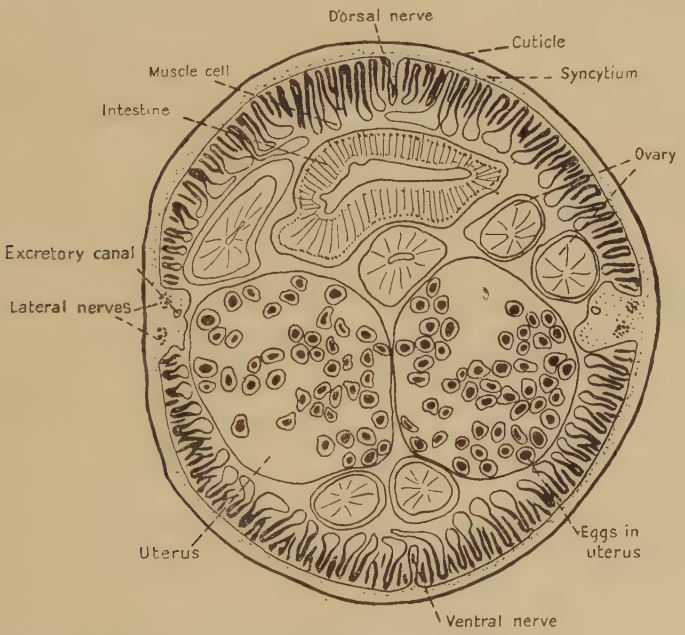

FIG. 46.—Diagram of a transverse section of *Ascaris lumbricoides*. × 33. (Drawn from a slide lent by Professor C. L. Boulenger, M.A.)

representing the degenerated epidermis. Embedded in a dorsal, ventral, and two lateral thickenings of the syncytium are the dorsal, ventral, and lateral longitudinal nerves given off from the anterior nerve-ring. In the lateral thickenings are the lateral excretory canals which discharge their contents to the exterior by a single aperture in the median ventral line just behind the mouth. Next to the syncytium is the layer of muscles—these are characteristic of the Nematodes and consist of large cells

with contractile pillars whose outer ends are embedded in the syncytium and whose inner ends protrude into the general body-space, and when fully distended may completely fill it. This body-space is not a cœlom, but merely a cavity between the centrally placed alimentary canal and the muscles. The mouth is at the extreme anterior end and leads into the œsophagus. Thick muscular walls give it a powerful sucking action. The food of the parasite is the body-fluids of the host. The intestine is straight and often flattened. The rectum is short and opens to the exterior by a ventrally placed anus a little in advance of the posterior end. The paired ovaries are continuous with their ducts and the uteri unite to form a common vagina opening to the exterior by a median ventral opening near the anterior end of the body. The unpaired testis is also continuous with its duct. The vas deferens opens to the exterior at the posterior end near the anus. The eggs are discharged into the intestine of the host and vast numbers are produced. They are ovoid and the smooth thick shell is coated with albumen. They measure ·05–·07 inch × ·04–·05 inch. Within the egg the embryo develops, and this can withstand considerable

FIG. 47.—Camera lucida drawing of a single muscle cell of *Ascaris megalocephala*. (Much magnified.)

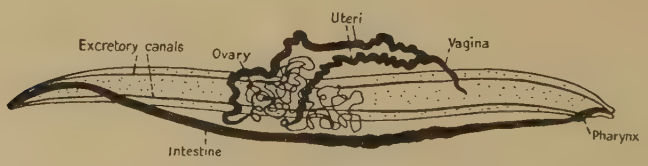

FIG. 48.—Dissection of *Ascaris lumbricoides*. × ½. (After Shipley.)

variations in both moisture and temperature. These eggs may be transferred to fresh vegetables, etc., by the wind or by house-flies and eaten by man. Within about a month or two after leaving the uterus the larvæ are fully developed, and the digestive juices of the human breaking

down the shell, the young comes out and begins feeding. The larva is carried with the portal blood-stream to the liver and thence to the heart and lungs. At this stage the larva, having become too large for the capillaries of the lungs, breaks through into the lung-cavities and so to the pharynx and thence to the alimentary canal. During this migration, development takes place, and by the time the alimentary canal is reached the organism is an adult. Serious bronchial symptoms, internal abscesses, and appendicitis have been mentioned as caused by the presence of *A. lumbricoides*. In some cases the effect on the host may be nil, or at least there is an appearance of toleration ; but in others, even though the conditions may not be as serious as those mentioned above, there are gastro-intestinal disturbances caused; not only by the irritation of the parasite, but by the effect of toxins produced by it. The patients lose weight, become pale, and have that characteristic grey shadow under the eyes. Medical treatment is a question for the doctor, but it might be mentioned here that purgatives evacuate the alimentary canal and enable the santonin, then administered, to kill the parasite. The treatment has often to be repeated three or four times, till an examination of the fæces gives a negative result for eggs.

Family Oxyuridæ (Cobbold, 1864)

Oxyuris vermicularis (Linn., 1758), Bremser 1819 syn. *Enterobius vermicularis* (Linn., 1758), is a much smaller organism than *A. lumbricoides*, as its measurements indicate—female 10 mm., and the male 3·5 mm.—hence it is often called the pin- or thread-worm. It is parasitic on man and monkeys, and infection is by the contamination of food, most probably fruit and raw vegetables. The eggs, formed in immense numbers, leave the host with the fæces and measure 50–52 μ × 16–24 μ. In the case of children there is often self reinfection in their endeavour, during sleep, to allay the irritation of the anal regions. The digestive juices of the host liberate the embryos, which have by then lost the tadpole-like appear-

ance and become filiform. The males and females copulate in the small intestine ; after this the males die and the females, as a rule, pass into the large intestine, though they have been known to find their way forwards into the mouth. It is this wandering through the tissues that adds to the danger. The females frequently leave the host with the fæces.

Oxyuriasis is cosmopolitan in distribution. It is frequently accompanied by enterocolitis and, as already mentioned, extreme irritation of nose and anal regions, with a feverish irritable condition which should arouse suspicion as to the true state of things. Again it is for the doctor to recommend the treatment ; but the adult

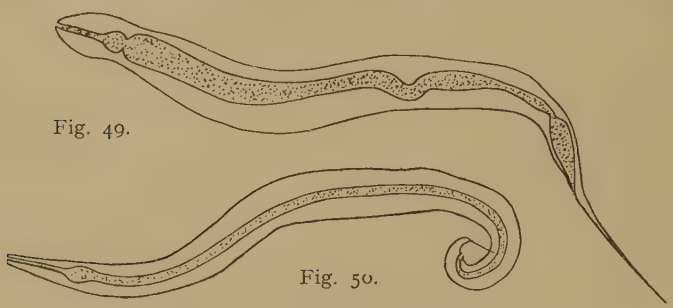

Fig. 49.—*Oxyuris vermicularis*, female. × 14.
Fig. 50.—*Oxyuris vermicularis*, male. × 33.

females are killed with injections of quassia, while the young forms, being higher in the alimentary canal, require strong purgatives and santonin and calomel.

Family Trichinellidæ (Ward, 1907)

This is a small Family of Nematodes, small in number and the individuals small in size.

Trichinella spiralis (Owen, 1835) is a small thread-like worm (♀ 3–4 mm., ♂ 1·4–1·6 mm.) which has spread from its original hosts, the black and sewer rat (*Epimys rattus* and *E. norvegicus*), to many mammals, including dogs, cats, pigs, etc., and most usually through the pig to man. They are world-wide in distribution and cause the disease known as Trichiniasis. It is by the flesh of the pig that

man becomes infected. The larva is to be found encysted in the muscles, usually those of the diaphragm, larynx, tongue, abdomen, and the intercostal regions. The cysts measure 400 μ × 250 μ, and lie with their long axis parallel to the muscle strands. The larva meanders through the tissues and its presence in the muscles causes inflammation and a thickening of the tissues round the cyst. This explains a stiffness and soreness of the limbs in cases of trichiniasis. In this condition the parasite is very resistant and can withstand a temperature of 80° C., so that a large joint incompletely cooked is a dangerous thing. Experiments show that refrigeration must be thorough, i.e. at a temperature of " at least 5° F. for not less than twenty days, allowing for a margin of safety of about ten days." Pickling does not affect them. By eating infected pig's meat, therefore, man is almost certain to take it with the larvæ uninjured by any of the usual methods of preparation. In the alimentary canal of man the cyst-wall is broken down and the larva emerges and passes into the duodenum, where it becomes adult. Copulation takes place in the duodenum and, as in the case of *Oxyuris vermicularis*, the males die and the females make their way into the lymph-vessels. Here they give rise, viviparously, to an immense number of larvæ, which are carried along to the muscles where encystment takes place, causing a soreness of the muscles which is rheumatoid in character. As with the other Nematodes described, the wanderings of the parasite are dangerous because of the possibility of the spread of bacteria. Fortunately a severe case of trichiniasis is now becoming rare, but a mild attack is unpleasant enough, with the symptoms, developed to a greater or less extent, of muscular fatigue, diarrhœa, intestinal hæmorrhage, œdema of the face, remittent fever, and leucocytosis. The cure is again a repeated evacuation of the bowels to get rid of the helminth visitants.

FIG. 51.—*Trichinella spiralis*. Camera lucida drawing of the larva encysted in the muscles.

CHAPTER V

PHYLUM ARTHROPODA

These are metamerically segmented animals, usually covered by a chitinous exoskeleton. The appendages are generally jointed and at least one pair is used as mouth-parts. A cœlom is present, but it does not constitute a large body-cavity. The large body-cavities are blood-spaces or blood-sinuses.

The Phylum Arthropoda includes an immense number of organisms ; indeed its species outnumber the sum-total of species in the rest of the animal kingdom.

A study of a list of the Classes of the Phylum will reveal that within the Arthropoda there is an infinite variety of form, colour, habitat, habits, and life-history. The Phylum provides examples exhibiting all the important phenomena of hermaphroditism, parasitism, dimorphism, polymorphism, symbiosis, etc., etc. There are sea-water forms found at all depths, e.g. crabs, lobsters, prawns, and shrimps ; fresh-water forms, e.g. many aquatic insects and fresh-water crustaceans ; land forms in every variety of situation, e.g. many insects, spiders, land-crabs ; and many have specialised organs of flight, e.g. the vast majority of the insects. The two Classes which concern the student of Social Science are the Insecta and the Arachnida. The former will be discussed first.

Class Insecta

Members of this class are all highly specialised. They are terrestrial and breathe air by means of a system of tracheal tubes, which, ramifying among the tissues, conveys the air to all parts of the body. The tracheal system consists of spiracles, openings provided with structures for the control of the air entering the tracheal

tubes, and the tubes themselves, strengthened by spiral thickenings which keep the tracheæ in an expanded condition, allowing for the free passage of the air.

FIG. 52.—Tracheal system of an insect. (After Folsom after Kolbe.)

The regular metameric segmentation of the more primitive Arthropods is frequently masked by a union of the segments and a disappearance of their outlines. The general body-mass in the Insecta is divided into three distinct regions, the head, thorax, and abdomen.

The *head* is formed by the union of six segments and is often a rounded structure on which are mounted the eyes and the appendages known as antennæ, mandibles, maxillæ, and labium or fused second maxillæ. There is every variety of form and function exhibited by these appendages, but the following will give a general idea of their uses. The antennæ are usually long, delicate, jointed structures, highly sensitive and sometimes bearing auditory, olfactory, tactile, and other organs. The mandibles are strong and heavily chitinised and used for tearing and biting. They may be reduced to stabber-like

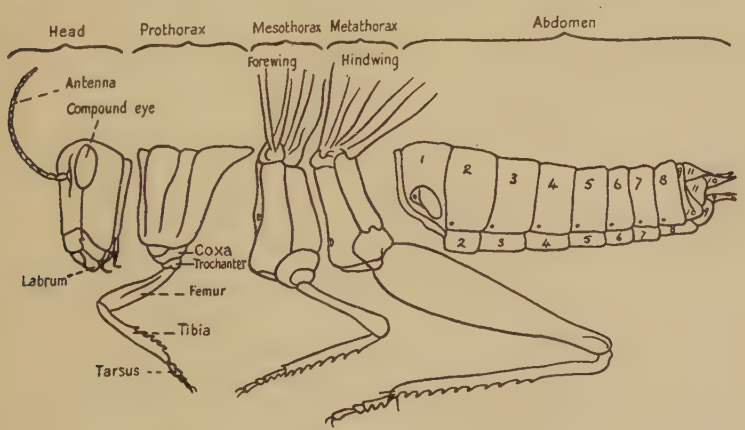

FIG. 53.—Diagram of the external anatomy of an insect (grasshopper), showing the various parts of the body. (After Herms.)

structures used for piercing or they may be abortive or absent. The first maxillæ are highly sensitive, having a sensory palp, while in some cases the particular part known as the lacinia is a most efficient cutting organ. The second maxillæ are usually fused and form a labium or lower lip. They are often sensitive and bear labial palps. Two other structures, the epipharynx and hypopharynx, developed respectively from the dorsal and ventral pharyngeal lining, often assume an important part in assisting and supplementing the other mouth-parts.

The *thorax* is behind the head and generally easily distinguishable from it. Often the three segments, pro-, meso-, and metathorax, are quite obvious and sub-equal in size. In other cases, as in the Diptera, the mesothorax is much enlarged and at a cursory glance the thorax appears to be of one segment only. All insects are characterised by possessing three pairs of legs in the adult condition, one pair on each of the thoracic segments. Having six legs, an insect can always have three on the ground while three take a new position, and this tripod arrangement greatly helps to give these creatures their firm footing. The first pair of legs is directed forwards and the second and third backwards, and thus variety in action is gained and walking is accomplished by a "pull-and-push" method. Some insects are primitively wingless, in others the wings are suppressed. Some have two pairs borne by the meso- and metathorax respectively; these may be all used for flight or the mesothoracic pair may be thickened to form wing-covers or elytra. In the Diptera there is only one pair, and in the position of the

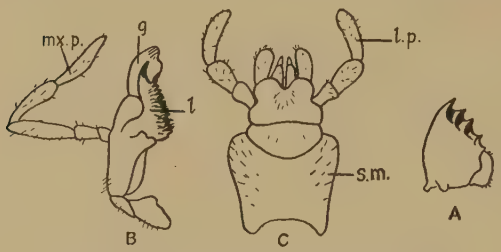

FIG. 54.—Mouth-parts of the cockroach.

A. Mandible, *B*. 1st maxilla, *C*. labium. *g*. galea, *l*. lacinia, *mx.p*. maxillary palp, *l.p*. labial palp, *s.m*. submentum. (After Imms.)

metathoracic pair are the balancers or halteres. The veining of the wings is used as a diagnostic character and shows great variation even within the different orders. In some cases it is of specific value.

The *abdomen* is composed of eleven segments and sometimes an additional portion known as the telson. In the less specialised insects the segments are clearly defined, but in others the posterior segments may be modified in a variety of ways and telescoped within the others. In many insects the eleventh segment bears a pair of cerci—jointed spine-like structures.

The digestive system is a tube passing from an anteriorly placed mouth to a posterior anus. Primarily it consists

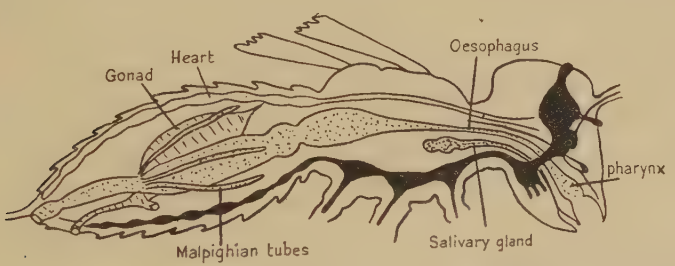

FIG. 55.—Diagram of the general body structure of a primitive winged insect. Central nervous system = black, alimentary canal = spotted, heart and aorta = clear. (After Imms.)

of a stomodæum (or anterior portion), and mesenteron (or stomach region), and the posterior intestine (or proctodæum). In many of the blood-sucking insects there is a crop in which the food is stored, to be regurgitated and reswallowed later, after the manner of chewing the cud. The glands of the alimentary canal are of great importance. In many the salivary glands are large, and their secretion plays a necessary part in the feeding process of the insect. The Malpighian glands are excretory, the cæcal glands are digestive, the rectal glands may be of two kinds, digestive or respiratory. There are also poison glands and wax, scent, or silk glands.

The blood vascular system is characteristic of the Arthropoda and consists of a dorsally placed elongated

heart in the abdominal region and a dorsal aorta passing forwards into the thorax. The heart has paired lateral openings or ostia which carry the blood into great sinuses.

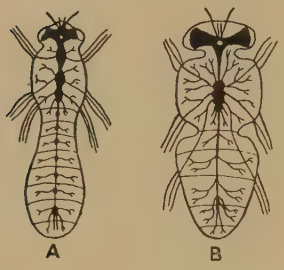

Fig. 56.—Diagrams of the central nervous system in: *A*. a gnat with no concentration of ganglia, *B*. a fly with extreme concentration of ganglia. (After Folsom after Brandt.)

In the more primitive insects the central nervous system consists of a dorsally placed supra-œsophageal nerve-mass united by a pair of commissures to a sub-œsophageal nerve-mass on the ventral side. The œsophagus is encircled by the commissures which form the œsophageal ring. The ventral nerve-cord passes backwards as a double chain. In each segment of the thorax is a paired ganglionic mass. In the abdomen there are nerve-ganglia united by paired connectives. From the ganglia nerves are given off to the eyes, wings, legs, and other parts of the body. In the more highly specialised insects the nerve-chain is considerably shortened and the ganglia unite. The most extreme case is that of the house-fly, where coalescence has taken place to such an extent that there are only two ganglionic masses, the cerebral mass and the mass lying in the thorax formed by the union of the thoracic and abdominal ganglia.

Fig. 57.—Female reproductive organs of *Blatta orientalis*. × 7. (After Miall and Denny.)

The Insecta are normally diœcious, that is, the male and female organs are in separate individuals. The term "neuters" often applied to "worker bees" is misleading; these are females whose genitalia are not developed, so, "though not occupied with the direct physiological processes of reproduction," these creatures are

of a definite sex. The majority of insects are oviparous and the eggs are developed in egg-tubes. These vary greatly in number (1–3000) and are arranged in two groups, each group discharging its eggs into a separate oviduct. The oviducts open into a common vagina. The testes are paired ; they vary from simple sacs to convoluted tubes with many follicles. When the sperms are formed they are frequently stored in large seminal vesicles, the testes disappearing.

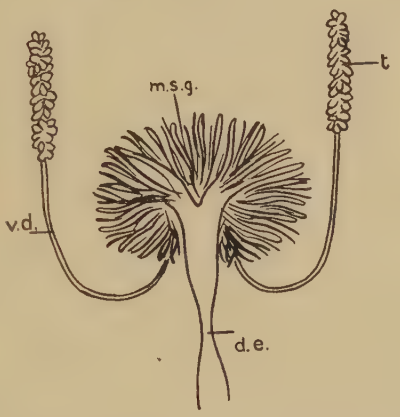

Fig. 58.—Male reproductive organs of *Blatta orientalis*. × 5. *d.e.* Ductus ejaculatorius, *m.s.g.* " mushroom-shaped gland," *t.* testis, *v.d.* vas deferens. (After Miall and Denny.)

Development and Metamorphosis

This is not the place for more than an outline account of the important features of these processes, and this is given in order that the reader may be able to follow the chapters dealing with the Insecta. The subject is a wide one and recent years have added enormously to its scope. Readers are referred to " A General Text-book of Entomology," by A. D. Imms.

It has already been stated that the Insecta are normally diœcious and egg-laying, but there are examples among them of hermaphrodite and viviparous forms. Many give rise to young parthenogenetically. The eggs are deposited in a variety of places—sometimes considerable care is shown by the parent in placing them where there will be an abundance of food for the young when hatched, and in other cases there seems to be no exhibition of parental care or forethought of any kind. After deposition, embryonic development begins, taking place at the expense of the store of yolk with which most insectan eggs are packed. In some of the more primitive Orders of

Insects the young that hatch out are in many respects very like their parents. Referring to Figs. 63 and 64, depicting the young louse, it will be seen that this is the case—the larva differs from its parent only in matters of proportion, it is of a minute size, it is not sexually mature, but it is able to feed itself and lead an independent life. At subsequent intervals after periods of feeding the chitinous covering is cast and the one formed in its place is more like that of the parent. After the final moult the adult form is assumed and the genitalia are developed. Turning now to the case of the beetle, Fig. 107 gives some idea of the larva produced from the egg of *Calandra oryzæ*. It is a little maggot-like creature, whitish-yellow in colour. After a period of feeding and rapid growth, the outer skin is cast, and eventually, when the final moult is over and the larva is fully fed and full grown, it becomes quiescent and pupates. Now the period of post-embryonic growth ceases, and during pupation there is a time of post-embryonic development when the organs of the imago are built up from embryonic masses of tissue, the imaginal discs, by the aid of the food-store derived from the breaking-down of the old larval tissues. Thus there is a series of phases in the life-history, egg, larva, pupa, and imago ; each phase is distinct and differs markedly from the others. In this case metamorphosis is said to be complete or indirect, while in the louse metamorphosis is incomplete or direct and there is no abrupt change between the phases.

In the following chapters certain Orders of Insects are singled out for special consideration and various species are described because they come under one or other of the headings " Harmful or Useful Animals," and this from the point of view of the student of social science.

CHAPTER VI

INSECTA

Order THYSANURA

Large antennæ present ; 10 or 11 abdominal segments ; a median abdominal process between a pair of long anal cerci ; the body flattened dorso-ventrally, covered with fine scales ; the integument soft ; the legs simple and sub-equal in length ; mouth-parts mandibulate, and either free or enclosed in the head ; eyes small ; segments of the body simple and undifferentiated.

Family Lepismidæ

The mouth-parts are exserted, median process on the abdomen ; there are 11 abdominal segments ; the eyes are simple.

Lepisma saccharina L. is a pest very common in England, doing injury to books, papers, labels, and even to starched clothing. It is a small, delicate, silver-coloured insect, nocturnal in habit and shunning the light, hurrying quickly to cover when it is disturbed. It is known by many colloquial names, Fish-moth, Silver-fish, or Slicker. It feeds on vegetable matter, such as sugar and starches, found in the above-mentioned articles—in the dressing of the paper, the gum of the labels, and the starches in the clothing. In warm climates it is found on woollen and silk clothing, i.e. on fabrics of animal origin. *L. saccharina* is about $\frac{1}{3}$ inch in length, with very large and prominent antennæ. It was first described by Hooke in the *Transactions of the Royal Society* in 1665.

Lepisma domestica (Pack.) (*Thermobia furnorum*).—This is another species and perhaps even more common in England than *L. saccharina*. Its name, " Fire-brat," is appropriate, owing to its preference for the warmth of

fire-places, hearths, and stoves. In other words, it is to be found in dry, warm situations, where it can obtain sugar, crumbs, or fat, dropped round the cooking-stove. This species is broader in the body and the dense coat of scales is of a silver colour, mottled with dark patches. It is about $\frac{1}{2}$ inch in length.

CONTROL.—The use of pyrethrum powder is valuable in exterminating this pest ; it should be sprinkled on bookshelves and round the hearth and cooking-stove. Poisoned bait of flour and white arsenic is also recommended, spread on pieces of cardboard and placed in exposed positions in the runs of the insect. With regard to clothing, this should be frequently handled and shaken in the air and exposed to the sun. It is worthy of note that in our colder climate of England it is not likely that *L. saccharina* or *L. domestica* will become a serious pest.

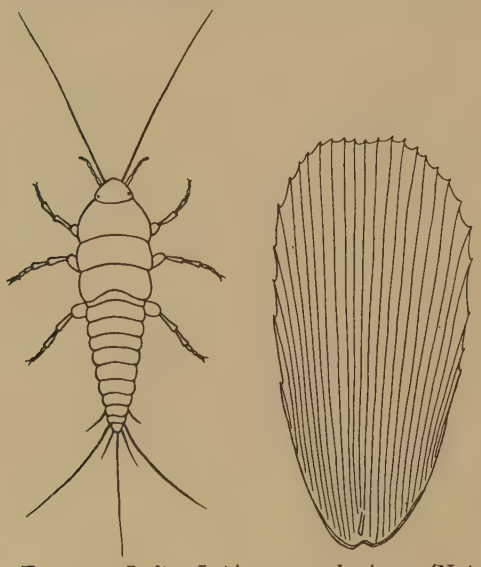

FIG. 59.—Left, *Lepisma saccharina.* (Nat. size 9 mm.) "Silver-Fish," "Fire-Brat," "Slicker." Right, scale of *Lepisma saccharina.* × 230.

Order ANOPLURA—Sucking Lice

The Anoplura is a small Order constituted to include the sucking lice, small wingless insects, found as ecto-parasites on many mammals, including man, obtaining their nourishment by sucking the blood of their host. In structure and life-history they exhibit many characters generally associated with insects specially modified for a

parasitic mode of life, and it is this which renders it difficult to determine their true relationships. At one time they were classed in the Order Hemiptera, now known as the Rhynchota, but removed when the structure of their peculiar sucking and piercing mouth-organs was shown to be so very different from that typical of the Rhynchota. They have also been closely associated with the Order Mallophaga, or Bird Lice. In all probability these two orders have been derived from a common ancestor. However, the sucking lice are now included in a separate order, but placed near that of the Mallophaga.

There are many old records of the sucking lice, and it is undoubted that they were known to Aristotle, while there is mention of them in the works of Theophrastus, Aristophanes, and many others.

There are three kinds of lice found on the body of man :

Pediculus humanus L., race *capitis* (Nuttall), head louse.

Pediculus humanus L., race *corporis* (Nuttall), body louse.

Phthirus pubis L. (1758), crab louse.

All are characterised by having the body depressed dorso-ventrally and covered by a tough leathery integument ; the legs are strong and clawed. The segments of the thorax are fused. The life-history shows an incomplete metamorphosis, the young resembling their parents.

The head louse and the body louse resemble one another very closely ; the question has been debated whether they should be considered as races of one species or each as a separate species. The crab louse, as the name suggests, has a short, broad body like that of a crab.

Pediculus humanus corporis (Fig. 64, *D*), the body louse, has a roughly oval body, much longer than broad, but narrower in front than behind. The average length of the male is about 3·2 mm., while that of the female is 4·1 mm. The head is distinct from the thorax ; it is conical and ends anteriorly in a blunt point. The upper surface is heavily chitinised, giving a strong support to the piercing mouth-parts, and the head itself is further strengthened by the " apodemes," i.e. two prongs of chitin passing from

the dorsal posterior border of the head under the chitinous covering of the thorax. The antennæ are inserted about the middle of the lateral border of the head. They are five-jointed and always in motion, continually making use of the sense-pits situated in the terminal joints. The eyes are inconspicuous, as might be expected in a parasitic type.

The mouth-parts are very difficult to compare with those of other insects. They are described and figured by Peacock. The stabbing apparatus is encased in the " stabber " sac, which is really a diverticulum of the ventral wall of the gut ; this sac is seen lying below the pharynx,

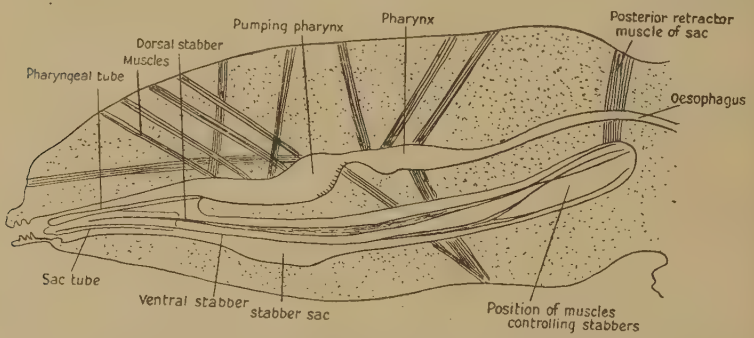

FIG. 60.—Diagram of the mouth-parts of the louse as seen in a longitudinal median section of the head. (After Peacock.)

extending to the posterior end of the head. Contained in the stabber sac are the ventral and dorsal stabbers ; these are chitinous mouth-parts controlled by muscles at the back of the stabber sac, having toothed anterior points which lacerate the skin of the host. The stabbers work backwards and forwards in the sac-tube. The salivary pipe, fed by the salivary ducts at the back of the stabber sac, passes ventrally to the dorsal stabber and pours the saliva into the wound. The blood of the host is pumped up into the pharyngeal tube and makes its way through the pharynx to the œsophagus. The saliva poured into the wound prevents the coagulation of the blood.

The thorax is small and bears three pairs of strong legs provided with powerful claws. The abdomen is ovoid and

exhibits a distinct sexual difference, the female bearing the gonopodia used during the laying of the eggs. The chitin covering the abdomen is darkly coloured at the periphery, giving an appearance of an artistic sepia-coloured margin. The spiracular openings are also outlined in the same way.

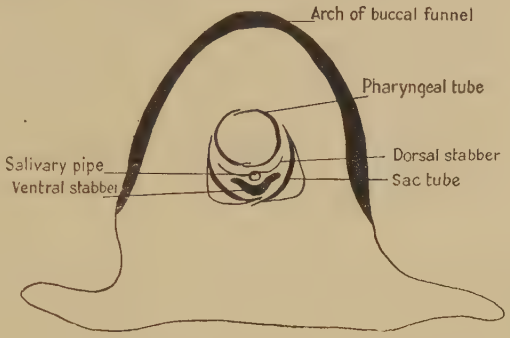

FIG. 61.—Transverse section of the anterior region of the buccal organs of the louse. (After Peacock.)

The life-history of the body louse has been a frequent subject of study, but it is only comparatively recently that the details have been worked out. The complete series of stages has been ascertained and fully figured by G. H. F. Nuttall. The eggs are small and oval and yellowish-white in colour; they are laid in the clothing or attached to the base of the hairs on the body. It has been shown that the deposition of eggs does not take place below 20° C. or above 37° C. One egg is laid at a time, and is carefully attached to the clothing or body-hair by an adhesive secretion which quickly hardens. The female lays about ten eggs a day and about 275–300 eggs in all. The larva, hatched after about 4–6 days' incubation, is very like the parent, but the proportions of the body parts are different, the head and legs being noticeably large compared with the abdomen. The larva moults three times before the adult form is reached; thus there are two nymphal stages, each showing an increasing likeness to the parent. The average length of time from the hatching of the egg to the final

FIG. 62.—Egg of *Pediculus humanus corporis* (body louse) attached to a hair. (After Patton and Cragg.)

moult is 11–12 days. The males live for about three weeks and the females about four weeks, so the complete life-story extends over five or six weeks. The adults are fertile about 24–36 hours after the last moult and frequent copulation is necessary. It has been said that lice can

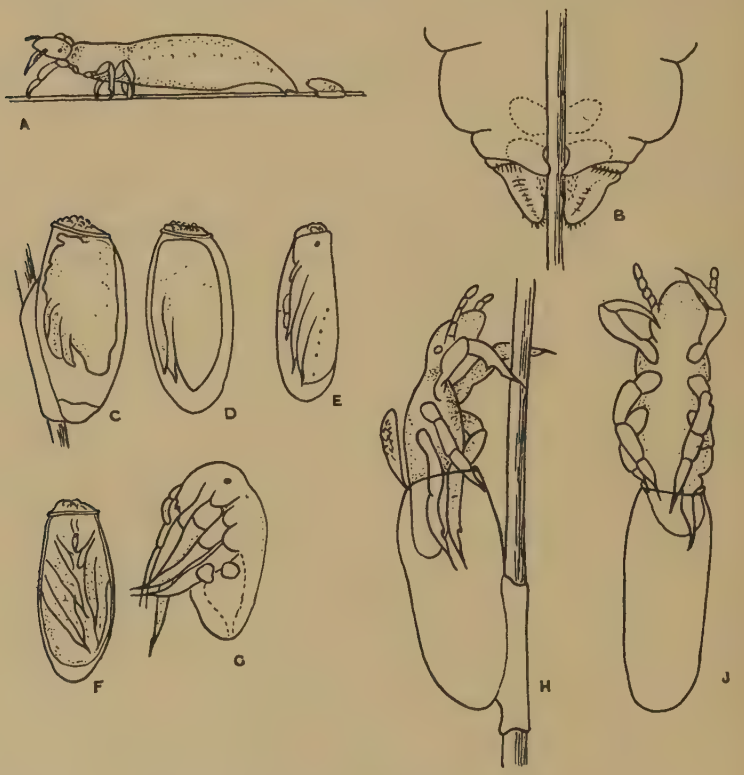

FIG. 63.—*Pediculus humanus corporis.*

A. The process of oviposition. *B*. The female holding the hair with the gonopods. *C–J*. The development and hatching of the larva. (After Nuttall.)

bring forth young parthenogenetically, but this statement has been proved to be incorrect.

Pediculus humanus capitis, the head louse, is slightly smaller than the variety just described, the male measuring about 2·45 mm. and the female 3·1 mm. in length. It can be distinguished from the body louse by the narrowness

of the anterior end of the thorax, the deep clefts between the segments of the body, and the shorter and thicker gonopodia of the female. This variety has been described as laying in all about fifty eggs in six days ; these are

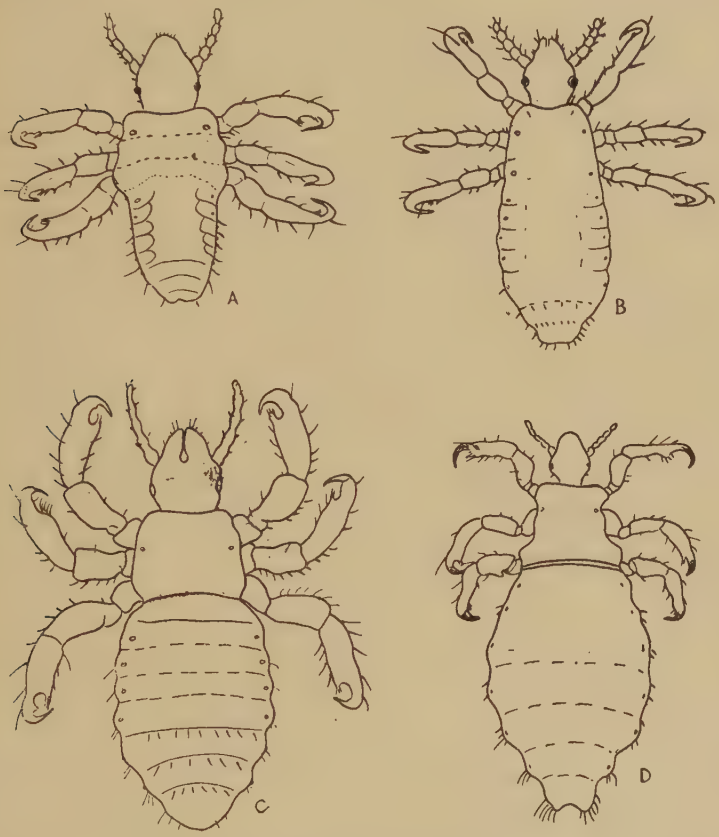

FIG. 64.—*Pediculus humanus corporis.*
A. The larva. *B*. First nymph. *C*. Second nymph. *D*. Adult female. *A, B, C* × 35. *D* × 12. (After Patton and Cragg.)

deposited on the hairs of the host's head, especially near the root, and are commonly known as " nits." Under ordinary circumstances the eggs hatch in about six days, the young becoming adult in eighteen days and a complete generation requiring a period of about one month.

Phthirus pubis, as already described, has a short body, not quite as broad as it is long. The female measures 1·2–2 mm. × 1·5 mm.; the male is about half this size. The anterior legs are slender with long thin claws, while the two pairs of back legs are stout, spreading laterally, and are provided with large claws. The body is white with a dusky patch on each "shoulder," and the legs are tinged with red. The fifth to the eighth abdominal segments bear lateral hook-like processes; those borne by the posterior segments are longer than those in front. The gonopodia of the female are triangular. Ten to fifteen eggs are laid, securely attached to the hairs of the host; these hatch in seven days and the young become mature in about fifteen days.

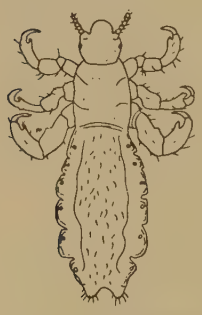

FIG. 65.—*Pediculus humanus capitis*, the head louse, female, dorsal view. × 17. (After Patton and Cragg.)

FIG. 66.—Egg of *Pediculus humanus capitis* attached to a hair. (After Gahan.)

HABITS OF LICE

Lice are most objectionable ecto-parasites found on the poor of most countries, especially in seaport towns and other crowded districts. They are more common and are found in greater numbers on children and old people. According to old medical treatises, the conditions seem to have been worse then than at the present time, and the death of the patient recorded in several very severe cases. Lice are more commonly found on the clothing nearest the skin, and are more prevalent during the winter months when cold weather is a direct discouragement to frequent washing and changing of clothes.

FIG. 67.—Eggs of *Pediculus humanus capitis* attached to a hair. (After Patton and Cragg.)

The body louse mainly infests the clothing closely applied to the body in the region of the back of the neck, shoulders, lumbar region, waist, wrists, thighs, and the external surface of the buttocks ; i.e. it is found very generally in the trunk region. The most usual places for oviposition are the chest and arm-pits where the eggs are to be found in great numbers attached to the hairs. The adults, too, are frequently found clinging to the body-hairs.

As a general rule, the head louse is found only on the head, especially in the region of the occiput and about the ears, but occasionally specimens may be found on the body-hairs.

Phthirus pubis, as its specific name implies, is most usually found in the pubic region, and also round the waist or on the parts where there are thick hairs, e.g. arm-pits and eyelids.

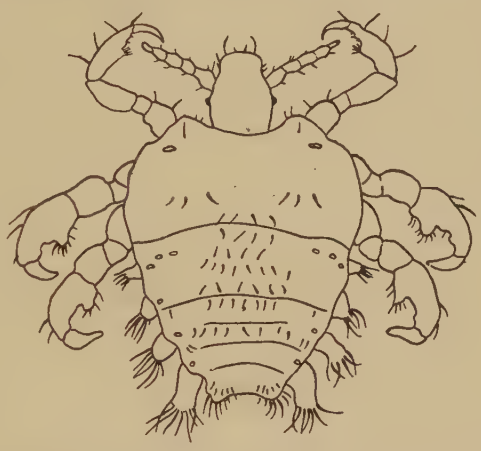

FIG. 68.—*Phthirus pubis*, female, dorsal view. The "crab-louse." × 43. (After Patton and Cragg.)

The spread of lice can be brought about all too easily in several ways ; contact with verminous persons is perhaps the most usual method. Lice are able to move with surprising rapidity, especially when hungry. It has been found by experiment that at a temperature of 18° C. *P. h. corporis* can cover a horizontal distance of 30 cm. in 1 min. 37 secs. *P. h. capitis*, at the same temperature, can climb up two hairs 20 cm. in length in 1 min. 25 secs. A body louse has been known to cover a horizontal distance of 90 cm. without a halt. Records such as these emphasise the ease with which lice can spread from one individual to another. It is a curious fact that lice, like

fleas, have some instinct which apprises them of the coming danger to themselves of the death of their host and of the consequent loss of food-supply and suitable surroundings. This instinct, causing the lice to leave in their dozens the dying host, has frequently been noted by those nursing typhus fever and relapsing fever patients, and the nurse should take care to protect herself against these infected migrants.

Contact with the clothing of verminous people is also a sure means of the spread of lousiness ; the playful exchange of hats amongst children frequently accounts for the dissemination of *P. h. capitis*. Wind is also an important agent in carrying the lice from the unclean to the clean, while that great enemy of man, the house-fly, has been shown to be a mechanical carrier of these vermin.

Lice bring many troubles to man ; they act as the carriers of certain diseases, but also by their mere presence they may cause blepharitis, conjunctivitis, eczema, dermatitis, deafness, and troubles of the lymphatic glands. They bring about a roughness and pigmentation of the skin ; and by the constant cutaneous irritation and toxic action of their saliva poured into the wounds, low fever is often caused. Lesser troubles are irritation, restlessness, and sleeplessness which, if continued for any length of time, cause anæmia. Up to the present the body louse has been proved to be the agent responsible for the spread of typhus fever, though fortunately the geographical distribution of this disease is more restricted than that of its carrier ; typhus being confined to cool and temperate climates and, showing a seasonal variation, disappears entirely in the summer months. After an infected feed the louse is capable of transmitting typhus, not only by saliva poured into the bite, but also by the person bitten rubbing into the wound the fæces of the louse or portions of its crushed body. As time goes by the louse becomes more infective. The transmission of the virus from an infected louse to its offspring is now proved.

Relapsing fever, another disease only found where there is personal filth and squalor, is disseminated by the head

louse and, as proved recently, by ticks. It has the same distribution as typhus fever and is a winter epidemic. The virus is also transmitted from one generation of lice to another. At present there is no proof that lice are the carriers of plague, typhoid fever, leprosy, or beri-beri.

Phthirus pubis occurs less frequently on man than *Pediculus* (only 3 per cent. of verminous people are found to have *Phthirus pubis*) and its importance in pathology is much less than that of *Pediculus*, since it is not known to be the carrier of any infective disease.

Control.—The prevention and treatment of lousiness has for centuries been a subject for study ; in the works of old scientists and in old medical treatises there are many allusions to this constant evil and its cure. Lousiness is exceedingly difficult to combat. The insects are prolific, their tenacity of life is great, and, strange to say, amongst the uneducated peasants of certain countries curious superstitions are a positive protection to the parasites, the belief being that the presence of a louse is a sure indication of good bodily health which would be seriously affected by bad luck if hospitality were no longer afforded to the visitants. The avoidance of lousy people, due care in the frequency and thoroughness of bathing the body and head and of changing the clothing, are in most cases all the prevention necessary. Those whose duties bring them into contact with lousy people would do well to remember that smooth-surfaced clothing gives the parasites less chance of obtaining a foothold, so that the nurse's starched dress and apron are her best protection.

For the actual removal of lice there are many and various methods, mechanical and otherwise. " Hand picking " is frequently seen amongst natives in the tropics, and hand picking and the use of the fine comb (" the Scotch louse-trap ") are the most usual methods adopted in this country for the cleansing of a not too serious infection of the head. The efficacy of the fine comb is greatly increased by using it hot or damped with vinegar or paraffin. If the infection is serious, the hair should be

cut and, if necessary, the head shaved as completely as possible ; the body should be shaved too when there is a heavy infection of head louse, in each case care being taken to burn the hair shaved off. The clothes may be treated either by steam, by hot water, or by heat :

Steam for about 5 seconds.
Heat, 55° C. for 5 minutes or 65–70° C. for 1 minute.
Hot water, 70° C. for 5 seconds.

Ironing with hot irons is also useful, but special care must be taken to iron the seams thoroughly.

A brisk rubbing of the body with a rough towel is usual for the removal of lice. It is of interest to note that this is the method recommended by Ludovico Buonarroti in a letter to his son Michelangelo when he left home as a boy to study art.

For the treatment of lice the following methods are recommended :

(1) Wash the head and hair in a 2 per cent. solution of carbolic acid, sluicing it well for at least ten minutes ; drain the hair and tie up the head in flannel, leaving the carbolic to soak in for one hour. This softens the scales and the adhesive attachment of the " nits." Use a pomade of carbolic and olive oil, 1 in 40, and after seventy-two hours wash the head well in warm water and soap, and dry. A good bath with weak carbolic is useful for removing body lice.

(2) Both the above species may be got rid of by the following method : Wash with mercuric chloride in vinegar, 2 in 1000, and then apply a " calomel pomade," i.e. mercurous chloride (Hg_2Cl_2) and vaseline, 1 in 20.

(3) Oil of turpentine sprayed on the head or body ; bandage the head overnight and wash well in the morning.

(4) *P. h. capitis :* Soak the hair in petroleum for three hours, wash well with soap and water. Repeat after three days.

P. h. corporis : Spray the skin with petroleum and rub well in with cotton-wool or a cloth.

(5) Spray head and body with paraffin and then take a warm bath.

Order SIPHONAPTERA

Antennæ small and inconspicuous, three-jointed, enclosed in grooves ; eyes simple ; mouth-parts adapted for piercing, and forming a tube for the suction of blood ; the thorax has three movable segments ; wings absent ; metamorphosis complete.

The members of the Siphonaptera, or fleas, are sharply differentiated from all other Insecta and the origin of the Order is still obscure. There is no very close connection with any other living order, but it is certain that it is more or less distantly related to the Order Diptera. Fleas are parasitic or ecto-parasitic on all groups of warm-blooded Vertebrates, except monkeys—though this statement will scarcely be believed by the populace. The Siphonaptera are exclusively blood-sucking parasites, and the body, compressed laterally, facilitates their movements between the clothes or fur or feathers of the host. Locomotion in the flea is mainly carried out by characteristic jumps—a feat of which it is capable because of the great development in length of the hind legs. For example, the human flea, *Pulex irritans* L., has been known to make a jump measuring 13 inches horizontally and 17$\frac{5}{4}$ inches vertically. For many years it has been understood that fleas are not only pests of great annoyance to the host, but that they are carriers of the bacilli of certain diseases, and are mainly responsible for the transmission of plague and kala-azar. In this respect the human flea, *Pulex irritans*, is not so serious an offender, though it has been proved that it can be a carrier of *Bacillus pestis*, which was described in 1894 by Yersin and Kitaseto and shown to be the causative organism of bubonic plague. The rat flea, *Xenopsylla cheopis* (Roth.), is the usual disseminator of plague. This is still one of the most dreaded diseases in India and, according to a recent statement, the annual death rate from plague is about one million. Fleas are also carriers of tape-worm cysts.

Pulex irritans L., though commonly known as the human flea, is to be found also on badgers, skunks, dogs, rats, and mice, while *Xenopsylla cheopis* and *Ctenocephalus felis* (Bouche), the rat and cat fleas, are frequent parasites on human beings. The distribution of *P. irritans* is cosmopolitan, and though the place of origin is uncertain, it was probably Europe. The locality most favourable to the growth and dissemination of fleas is one with a cool wet summer and a mild wet winter.

The head is flattened laterally and is without ctenidia or combs. The eyes are fairly large with some pigmentation. The club-shaped antennæ are located in grooves on the side of the head in such a manner that they do not project and impede movement. The mouth-parts are carried suspended from the head and are not enclosed in any sac or receptacle. They emerge from an aperture on the ventral side of the head, which is surrounded by a perioral ring of chitin. The mandibles are the most important mouth-parts and are the cutting weapons, for by means of their serrated edges they pierce the skin of the host. By the close application of the edges of the mandibles one to another, a tube is formed for the conveyance of saliva into the wound and for the passage of blood mixed with saliva from the wound into the pharynx of the flea. The maxillæ are provided with large sensitive palps, and the blades, or lacinia, are stout, conical, chitinous

FIG. 69.—*Pulex irritans*, female. The human flea. × 27. *a.* Antenna, *e.* eye, *l.* lacinia, *m.p.* maxillary palp.

structures. The labrum and epipharynx are united to form a long, slender, tactile structure, bearing tubercles which are probably sensory in function. The thorax consists of three distinct segments and ctenidia are not present. The abdomen has 10 segments, 7 of which can be seen clearly in lateral view, the sclerites, or chitinous plates, being arranged in a regular series. The three posterior segments are modified for sexual purposes. The 8th is a small one and in both sexes it is telescoped within the 7th. The 9th segment of the male bears the pygidium, or sensory plate, and claspers; while the 9th segment of the female bears the stylet and sensory hairs. The 10th segment in both sexes is telescoped within the body. The abdomen of the female is characterised by a rounded posterior end, turning downwards, and that of the male by the upward turn of the more posterior segments.

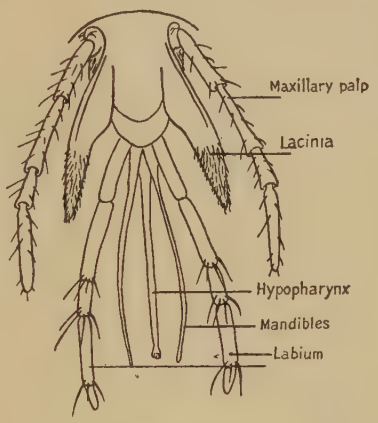

FIG. 70.—Diagram of the mouth-parts of a flea. (After Herms.)

FIG. 71.—Tip of the mandible of the cat flea. × 125. (After Patton and Cragg.)

With regard to the internal structure of the flea, it is interesting to note the powerful sucking pharynx and capacious mid-gut, or stomach. The salivary glands are of great importance, supplying as they do the saliva for preventing the host's blood from coagulating. There is one pair of testes; the penis and sheath are curved and strongly chitinised. The ovaries consist of eight ovarian tubules on either side. The nervous system exhibits primitive characteristics in that the supra-œsophageal ganglia and the sub-œsophageal ganglia are separated from one another; the thoracic

ganglia are distinct and separate and there are seven distinct abdominal ganglia.

Life-history and Habits

The eggs, though small, are proportionately large, being about one-third the size of the parent. She has been known to lay as many as 450 eggs. They are oval and pearly-white, and are deposited at random, singly in the bed of the host or in cracks and crevices of the room, particularly the cracks of boards under the carpets, out of the light. The eggs hatch in about 2–4 days, according to the temperature and humidity of the atmosphere. The larvæ are minute maggot-like organisms, consisting of a head and 13 segments. The head bears the antennæ, with sensitive hairs, a stout, serrated pair of mandibles and

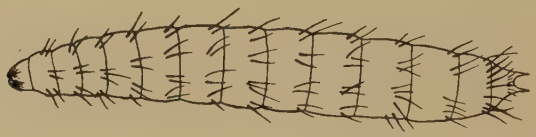

Fig. 72.—Larva of *Pulex irritans*. × 14.

maxillæ with sensitive palps ; on the dorsal side of the head is a tooth-like process with which the egg-shell is broken. There are no true legs nor pseudopods, but the body is sparsely covered with bristle-like hairs which greatly aid the wriggling movements so characteristic of the larvæ. Until recently the food of the larva presented a great mystery, but it is now understood that the main source of nourishment is the unclotted blood, regurgitated or defecated by the adult ; for the larva is not provided with sucking mouth-parts. There are two moults during the larval life, the three stages only differing in size. When fully grown, the larva spins a silken cocoon in which it pupates. Dust and particles of refuse become attached to the cocoon, giving it the appearance of a little heap of rubbish hidden in the cracks and crevices of the wood-work. The length of larval life varies according to the temperature and humidity and can be anything between

9 and 202 days. The pupal stage may be comparatively short, or again it may vary within wide limits, according to circumstances, the records being between 7 and 239 days. The pupa is a soft whitish structure and the gradually forming mouth-parts and appendages can be clearly seen when the pupa is removed from the cocoon. The pupa seems to be very sensitive to vibration, which accelerates the emergence of the adult. The adult flea has a much longer life than was first supposed. Lefroy records that a flea receiving food regularly lived as long as 513 days, while an unfed flea can live for 125 days. In normal life the flea is nocturnal. It usually feeds only once in the twenty-four hours, but should it be disturbed it will endeavour to complete its meal, and this has given rise to the supposition that the creature takes nourishment at very frequent intervals. In Southern Europe, where the temperature is fairly warm, the entire life-cycle from egg to adult can be passed through in so short a time as nineteen days.

Fig. 73.—Pupa of cat flea removed from the cocoon. (After Patton and Cragg.)

As already stated, *Pulex irritans* has been proved to be the carrier of the plague bacillus. The bacillus, sucked up with the blood from a plague patient, becomes lodged in the stomach of the flea. Here it multiplies rapidly, infecting everything that enters the stomach. Thus the defecated blood is highly charged with active plague-causing organisms. The persons bitten frequently infect themselves with this fæcal matter in an effort to allay the irritation. Moreover, the bacillus multiplies so rapidly that the flea's stomach may be completely blocked. The diseased and thirsty flea, now unable to digest the frequent meals of blood, regurgitates them, contaminated with plague bacillus ; generally these regurgitated meals are forced into the wound in the skin of the host. Thus the flea can transfer the bacillus to its host by either of two methods.

The larva receives the infection by contaminated feeds, but the bacillus has not been known to survive the changes of the pupal stages and the adult flea is harmless unless reinfected.

Control.—Extreme cleanliness is perhaps the greatest means of control, personal cleanliness consisting in frequent bathing and changing of personal and bed linen, and household cleanliness resulting from the thorough cleaning of rooms and the regular removal of dust collections. Avoidance of contamination is not always possible, but it should be remembered that fleas are readily acquired not only from unclean people, but also from stables, hen-houses, and from such animals as rats, mice, cats, and dogs. Pet dogs should be carefully groomed and, if infested, rubbed with a mineral oil emulsion and washed. Cats may be rubbed with powdered naphthalene or sprinkled with pyrethrum powder. It is easy to keep their bedding in good condition if it is dry and thoroughly cleansed, aired, and well shaken every day. For the clearing of an infested house numerous methods can be recommended, each having as its aim the destruction of the flea in its various stages of life-history, but all these processes should be preceded by the destruction of rats and mice and by the disinfecting of all pet animals. It is of great importance to remember that the flea, like the louse, has a strong instinct of the impending danger to itself in the death of its host, and should rat poison be used, it will kill the rats but will cause a migration of the flea population from the dying rat or mouse to pastures new. All floors, walls, and, where possible, furniture should be well washed with soap-suds to which a little 5 per cent. formalin has been added. A solution of naphthalene in benzine (light petroleum) may be poured into cracks and corners and will destroy the flea in all its stages. Rooms with a heavy infection should be closed for a couple of days after the floors have been well sprinkled with flaked naphthalene. Potassium cyanide may also be used, but with great care, $2\frac{1}{2}$ oz. to 1000 cubic feet of space. Flea traps are of some

service and may be quite simple. Delanoe recommends the placing of a fairly large shallow vessel on the floor of the infected room ; into this should be put water with a covering layer of oil and a night-light in the centre. The fleas are readily attracted to the light, especially if the room be darkened, and jumping towards the light they will fall back into the oil, from which they cannot make their escape.

CHAPTER VII

INSECTA

Order RHYNCHOTA

FOUR pairs of wings, the mesothoracic pair being either membranous or half horny and half membranous. Both pairs of wings may be absent in parasitic species. Mouth-parts suctorial—forming a beak—used for sucking the sap of plants or the blood of Vertebrates. Antennæ 2–10 joints. Metamorphosis usually incomplete, but complete in the case of the winged males of the Coccidæ. The wings, if present, are developed as lobes outside the body.

Sub-order 1. HOMOPTERA

Both pairs of wings membranous.

Family COCCIDÆ

This is an anomalous group whose members show many variations from the so-called type of the Order Rhynchota. There are great differences in the appearance and habits of even closely allied species and many species exhibit sexual dimorphism to a marked degree. The males undergo complete metamorphosis and, in the winged types, are possessed of one pair of membranous wings, the metathoracic pair being represented by a pair of halteres, each furnished with a hook that fits into a pocket on the wing of the same side. In many species wingless males are developed at certain times of the year. The adult males have no organs for procuring food, the larval structures disappearing during metamorphosis. The adult females are always wingless, the body is reduced to a mere scale or it may be gall-like. Many of the female coccids live on plants and secrete a waxy or gummy substance. It is in the cavities of this secretion that the

female may be found embedded in a chamber of her own making and out of which she can never emerge. Reference to the text-books dealing with Entomology in relation to Horticulture shows that the Family Coccidæ includes some of the most serious pests of fruit trees, etc. However, the genera described here are of some importance to man, not because of any harm they bring him, but on account of the secretions produced by the females or by the colouring matter accumulated within her body. *Coccus cacti* produces the red colouring matter, cochineal. *Tachardia lacca* secretes lac, commonly known as shellac, and *Coccus pe-la* secretes the China wax. In the case of each of the three products other genera and species provide these substances, but the above-named organisms produce the greatest quantity.

Coccus cacti.—The Cochineal Insect (now called *Dactylopius coccus* Costa)

The adult female, 2–3 mm. in length, is a peculiar object, completely dome-like in appearance, oval in outline with blunt anterior and posterior ends. The appendages are all small, the antennæ with 5–7 segments, and the three diminutive pairs of legs each terminate in hooks, and are so short that they do not project beyond the outline of the body. The mouth-parts are difficult of interpretation, but there is a long sucking proboscis, the insect obtaining its food by this means from the twig on which it lives. As maturity is reached, the females become a rich dark red colour, thus contrasting

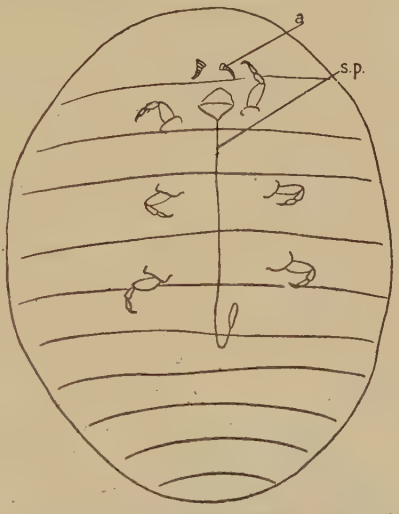

FIG. 74.—*Coccus cacti*, female, ventral view. The cochineal insect. *a.* antenna ; *s.p.* sucking proboscis. × 10.

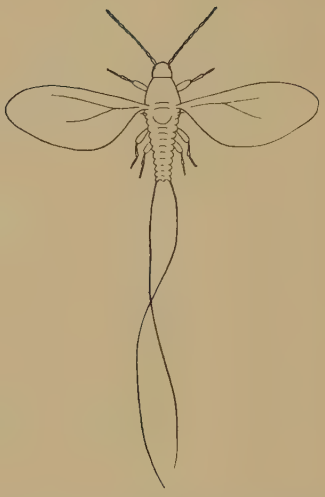

FIG. 75.—*Coccus tomentosus*, male. The cochineal insect. × 20. (After Newstead.)

with the mass of white waxen threads secreted by them and amongst which they lay their eggs. The winged males, also dark in colour, are short-lived and die after sexual union has taken place.

The " crop " is collected in the early morning and evening by brushing the females from the twigs into bags. They are then killed and dried by exposure to the sun or in an oven heated to 150° F. One pound weight is produced by 70,000 insects. When soaked in water these dried bodies give a rich permanent dye used, in conjunction with tin and aluminium mordants, for the production of red, carmine, and scarlet. Cortes in 1518, when he reached Mexico, found the natives using this dye. For a long time the Spaniards considered that these little red bodies were the seeds of plants, but Hartsoekar in 1694 and Leeuwenhoek in 1704 proved that this valuable dye was of animal origin. *Coccus cacti* is generally found on members of the Cactaceæ, hence its specific name, and most usually on various species of the genus *Opuntia* and

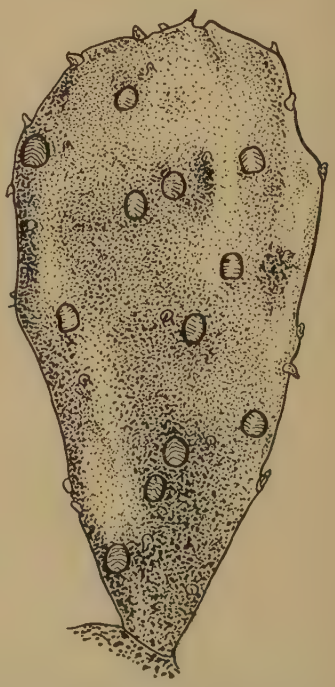

FIG. 76.—Female cochineal insects on a cactus. (After Bastin.)

on *Nopalea coccinellifera* (Salm-Dyck) in the Canaries. Both the plants and the insects have been introduced into other countries, so that the distribution of the cochineal insect at the present time is as follows: Mexico, Canary Islands, Algeria, Spain, West Indies, Madeira, Australia, Peru, Florida, California, Italy, Cape Colony, and Guatemala, where the insects are cultivated in considerable numbers. Natural cochineal used to be the principal dye for producing the scarlet for Army and hunting coats, but it is largely supplemented or replaced by the coal-tar dyes. These are cheaper though less permanent.

Tachardia lacca Kerr

Lac is a product of the east, especially of Bengal, Burma, the Central Provinces, and Sind. It is also collected in Egypt, Siam, and Assam, but the quantity obtained there is almost negligible—being only 2–3 per cent. of the world's output. Lac is produced by the activities of a small insect, *Tachardia lacca*, which is found on the young tender shoots of certain trees, the most important of which are the following: *Schleichera trijuga* Willd. = Ceylon oak; *Butea frondosa* Roxb. = the bastard teak; *Ficus religiosa* L., *Zizyphus jujuba* Lam., *Acacia arabica* Willd., and *Shorea talura*. The districts in which lac is found are neither very hot nor very cold and there is an annual rainfall of about 30 inches.

In the wild state, towards the middle of June, the minute larval insects fasten themselves, in great numbers, on to the young shoots, crawling towards them in their slow and sluggish way from the old branches where they were hatched. When cultivated, the trees specially prepared for their reception are inoculated by the planters, the young insects passing from the twigs on which they have travelled to the twigs of the growing trees. The insects must be well protected from the wind till they are fully established in their new home. When settled in their new abode, the young insects insert their long probosces into the bark and feed on the sap of the tree. Almost at

once they begin to exude resinous secretions over their entire bodies, so that they are soon covered with a kind of cocoon. These secretions frequently coalesce so that the twigs become encased in a great mass of resinous substance, and at irregular intervals in the mass are small cavities each containing an insect. At first there is no differentiation between male and female, the insects being all dome-like and measuring about 1 mm. in length. They are provided with three pairs of legs, a pair of black eyes, and a pair of long feelers. After about a fortnight of voracious feeding and consequent rapid growth, there is a distinct difference between the young males and the young females. The females have grown greatly and formed an irregular, globular case, perforated by three holes. From these holes tufts of white threads project; they are the external continuation of the tracheal system. So it can be understood that should the temperature rise and melt the resinous case, these holes will be choked and the animal will suffocate. The growth of the male is much less rapid, for at the same age it is only about one-fifth of the length of the female. Its case is smaller and more regular, and the male insect which emerges is wingless.

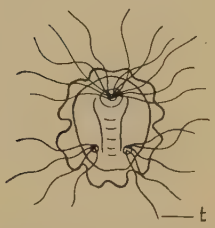

FIG. 77.—*Tachardia lacca*, female, 13 weeks old, dorsal view. The shellac insect. × 7·5. *t*. Tracheal tube. (After Misra.)

In the meantime the female has been developing—exuding more lac and acquiring a reddish colour—until, in August, it is impregnated by the male. It then quickly develops into a wingless, amorphous organism which might be described as a crimson sac containing a well-developed ovary. About the middle of September the female stops feeding, and the crimson sac dries and shrivels. The young hatch from the eggs and about the beginning of October swarm, as it were, from the very ashes of their

FIG. 78.—"Stick-lac" secreted by *Tachardia lacca*. × ¾.

dead parent, and creeping out by the holes in the resinous covering, make their way to the young and juicy shoots where they will begin their life.

In most plantations there are two crops a year, and so—to continue the story—the young insects swarming in October begin to feed, and exude lac by the end of July. Wingless and winged males emerge, fertilise the females, and then die. By the beginning of June the females stop feeding and, as before, lay eggs. These eggs in the middle of June give rise to the young larvæ, which will again swarm to the young twigs and begin feeding.

FIG. 79.—*Ceroplastes ceriferus*. a. Stem of *Antigonon*, with insects *in situ*, nat. size; b. wax test from below, showing under surface of adult female (black), nat. size; c. adult female, without wax test, side view, × 2; d. adult female, without wax test, dorsal view, × 2. (After Green.)

Coccus pe-la (Ericerus pe-la)

China wax is the product of certain insects, the most important of which is *Coccus pe-la*, a native of Western China, where it is found living as a parasite on the ash, *Fraxinus chinensis* L. *Ceroplastes ceriferus* Anderson is the wax insect of India. The insect secretes and surrounds itself with a mass of wax and the twigs of the trees are collected by the natives. The wax is hard and yellowish, with a melting-point of 81–83° C., and closely resembles spermaceti in its general appearance. It is used by the Chinese for making candles for burning in the sanctuaries on state occasions. When mixed with tallow, it is used for making the cheaper candles; it is also used in preparing furniture and leather polishes, and for sizing paper and cotton goods.

There is much speculation as to the reason why the

insect should secrete this wax ; it has been suggested that it is the result of a disease. This is improbable, but it is certain that when the insect is bred, only a very small amount of wax is produced.

Sub-order 2. Heteroptera

If wings are present those of the mesothorax possess a horny base.

Family Cimicidæ

Body oval and very flat ; head short and broad. Proboscis lies in a groove on the ventral surface of the head and thorax. No ocelli ; antennæ four-jointed. Wings in some cases practically absent ; elytra short and broad, leaving most of the abdomen uncovered. Tarsi three-jointed. The family includes about twelve species, all parasitic on mammals and birds.

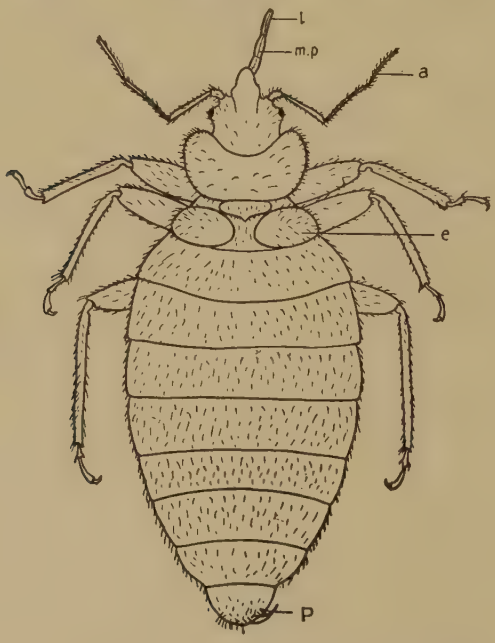

Fig. 80.—*Cimex lectularius*, male, dorsal view. The bed-bug. *a*. antenna ; *e*. elytron ; *l*. labium ; *m.p*. mouth-parts. × 10.

Cimex lectularius L. is the common bed-bug, and, though widely distributed throughout Europe and North America, it is found also in warmer climates, such as the Sudan, Suez, Egypt, Australia, South Africa, China, and the North-west Provinces of India. It is probably indigenous to the Eastern Mediterranean, and from thence it has established itself as an unwelcome inhabitant in

numerous localities, appearing first in the seaport towns and spreading rapidly to all the large inland towns. In all probability the bed-bug was brought to England towards the end of the sixteenth century. The scientific terms used for this organism are, of course, derived from the Latin, but the common name is harder to explain, though it is not difficult to see that it is a corruption of ghost or bogy or hobgoblin, suggested by the nocturnal habits of its possessor. The American name "Mahogany Flat" is also peculiarly expressive of the general appearance of this unpleasant creature. The presence of the bed-bug is always considered a sign of the neglect of cleanliness, and it is associated with dust, squalor, and overcrowding—characteristics of the slums which seem inevitably to be a part of all big cities and seaport towns. The bed-bug is not an ecto-parasite, but is rather a visitant to the human being, coming at night for its meal of blood and then disappearing into the bedding of the host and into the cracks and crevices of the floors, walls, ceiling, and furniture of the house. Hence it is probable that the bed-bug has only comparatively recently taken to sucking the blood of the human being and that before this habit was adopted it was found only on small mammals.

The bed-bug must not be confused with a small, harmless beetle, *Niptus hololeucus*, which often finds its way into blankets, etc., from the ivy covering the house. This is easily distinguished by the elytra covering the large flight wings characteristic of a member of the Coleoptera.

Cimex lectularius has a flattened, oval body of a deep red-brown colour and about $\frac{1}{4}$ inch in length. The head is short and broad with prominently projecting eyes set on its lateral borders. The antennæ are four-jointed, the proximal joint being very short and thick. The oral appendages when not in use are enclosed in the short labium which is folded under the head, having the appearance of a long prong extending about as far back as the anterior end of the abdomen. The mouth-parts are modified and reduced considerably. There is no epi- or

hypopharynx. The rostrum or labium has a deep groove at the distal end in which lie the delicate curved mandibles. These together form two channels—a larger food-passage enclosed by the concave inner surfaces of the mandibles, and a small salivary tube walled in by their thickened ventral edges. The maxillæ are the delicate stylets lying ventrally and laterally to the mandibles. They have sharply serrated edges. The exact use of these mouth-parts during feeding is still rather obscure, but it is certain that after several false beginnings, a puncture is made in the skin, saliva is poured into the wound, and blood is sucked up the food-tube. When undisturbed, a bug will suck for a considerable time, 3–10 minutes. It is able to fast for remarkably long periods.

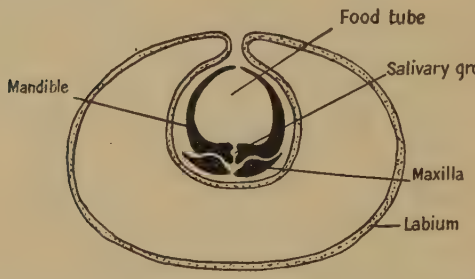

FIG. 81.—*Cimex lectularius*. The bed-bug. Transverse section of the rostrum. (After Cummings.)

The thorax consists of three segments : the prothorax large and conspicuous, followed by a narrow mesothorax bearing elytra which almost completely conceal the metathorax. On the ventral side of this last segment are the stink-glands which give the bug its characteristic unpleasant odour. The three pairs of legs are sub-equal in size and adapted for rapid progression. The abdomen is oval and flattened, slightly narrower in the male than the female. On the fourth segment in the female on the ventral side, to the right

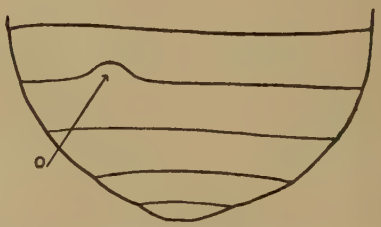

FIG. 82.—Diagram showing the position of the opening (*o*.) of the organ of Berlese in *Cimex lectularius*. Ventral view of the abdomen of the female. × 14.

of the middle line, can be seen the opening of the organ of Berlese, the pouch in which the male places the sperms. Berlese describes this pouch as a closed sac and the

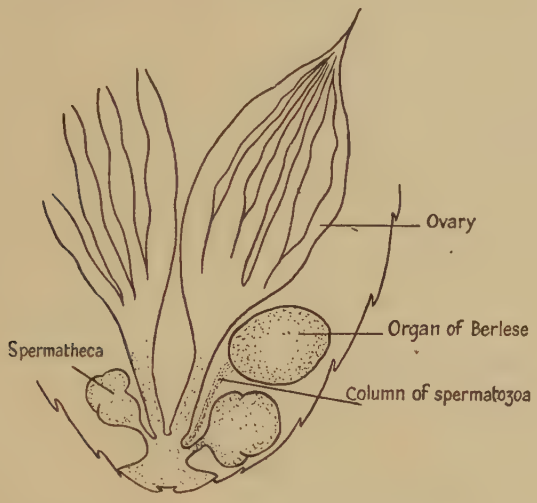

Fig. 83.—Diagram of the female genitalia of the bed-bug. (After Berlese.)

sperms make their way in a stream through the tissues to the spermathecæ, where they are stored until required to fertilise the eggs.

Life-history

As stated in the synopsis of the Order, metamorphosis is incomplete. The eggs are white and ovoid and are laid in batches of about eight or ten attached in some crack or cranny of flooring boards or bedstead. In about 5–21 days the eggs hatch and the young—small, and yellowish-white in colour—differ from the parent only in matters of proportion. The young moult five times before the adult stage is reached, and it is only at the last moult that the vestiges of the elytra appear. At each successive stage the young more closely resemble the parent and become darker in

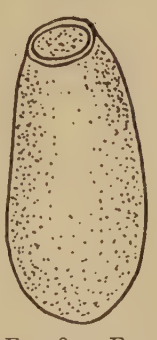

Fig. 84.—Egg of *Cimex lectularius*, the bed-bug. × 28. (After Patton and Cragg.)

colour. The female is known to live for about 6–8 months, and she lays in all about 200 eggs.

Control.—Cleanliness again, both personal and household, is of the utmost importance in controlling this pest, which has been proved to be a carrier of relapsing fever and plague. Cockroaches and red ants are their natural enemies, but, nevertheless, bugs are very difficult to exterminate when once they get a thoroughly good hold and are well established in a building. Their capacity for sustaining long fasts, together with their habit of making nightly excursions from an empty house to one where food is obtainable, adds to the difficulties. Thorough washing of floors, furniture, etc., is useful in slight infestations when the water is mixed with emulsified soap ; the mixture should also be squirted into cracks and crannies. Kerosene and benzine are also useful. Fumigation is efficacious : 3 lb. sulphur and ½ lb. saltpetre to 1,000 cubic feet of space burnt in a closed room for twenty-four hours. Hydrocyanic acid gas gives the best results, but this is a dangerous and expensive method. The skin of the patient may be treated with iodine and hydrogen peroxide, or with ammonia, menthol, etc.

CHAPTER VIII

ORDER ORTHOPTERA

1. Two pairs of wings ; the fore wings are often thick and heavy in texture, elongate and narrow in shape, with almost straight parallel sides. In some forms they take no part in flight. The hind wings are membranous, large in area, and when at rest are folded and concealed by the fore wings. In some cases the wings are reduced or absent.

2. The mouth-parts are modified for biting, the pronounced flexure of the head bringing them into close contact with the food.

3. Cerci present, and of varying lengths.

4. Metamorphosis is gradual, the young differing only slightly in general body-shape from the adult.

The insects belonging to this Order are well suited for life on land and are often grouped in two sub-orders according to their mode of progression—the Cursoria, the runners, and the Saltatoria, the jumpers. The organs of flight are used comparatively little. The males fly to the females, and, as in the crickets, the wings, rubbed together, produce a characteristic sound. The Orthoptera on the whole includes types of a large size, some of the largest insects being grouped in this Order.

The economic importance of some forms is considerable, the ravages of the locust having been recorded from the very earliest times. Cockroaches are also worthy of consideration under this heading, since the experiments of Herms, Longfellow, Barber, and others have shown that they can " pick up specific bacteria and can carry bacteria to human food." For a long time it has been known that they can act as an intermediate host in the life-cycle of Nematodes. It may be that in the future

they will prove to be an important enemy of man. Examples from only two of the eight families are selected for description here : the cockroaches, of the Family Blattidæ of the Sub-order Cursoria, with legs of only slightly differing lengths ; and the crickets, of the Family Gryllidæ of the Sub-order Saltatoria, with long hind legs modified for jumping.

Family Blattidæ

The Family Blattidæ includes some of the more commonly known Orthoptera, most people being familiar with one species or another of the cockroaches. They are most repulsive pests, nocturnal in habit. They run about quickly over everything in the kitchen and larder of a badly infested place, sometimes in such numbers that the appearance of the kitchen when suddenly lit up at night is a general mass of moving brownness. They produce a peculiarly unpleasant smell which is very characteristic and very hard to conceal. The term " black-beetle " is often used for these creatures, but this is incorrect, for neither species is black and they are certainly not beetles.

The two cockroaches most commonly known are the common or Oriental cockroach, *Blatta orientalis* L., and the German cockroach, *Blattella* (Ectobia) *germanica* L. The American cockroach, *Periplaneta americana* L., is found in hot-houses and heated warehouses, but only rarely in dwelling-houses. The Australian cockroach, *Periplaneta australiasiæ* Fabr., may be present in great numbers in greenhouses, where it can satisfy its special liking for a vegetarian diet, but it is only rarely found in houses. The first three cockroaches are exceedingly voracious and most human food seems to be acceptable, besides a variety of other diets—the starch in paper or clothing, the skins they themselves have cast, and the dead bodies of their fellows. But as they are able to fast for considerable periods and can conceal themselves in inconceivably small places, it is not surprising that they have spread rapidly from place to place, and mostly along the trade

routes. It is probable they were still rare in England in the latter part of the eighteenth century.

Blatta orientalis is about 25 mm. in length and shows marked sexual differences, the wings in the female being reduced to a very rudimentary condition. The wing-cases and wings in the male are larger, leaving only about one-third of the abdomen exposed. They are dark brown in colour, darker than those of the other cockroaches, and this has led to the mistaken appellation "black." So common is this species in England that, though originally

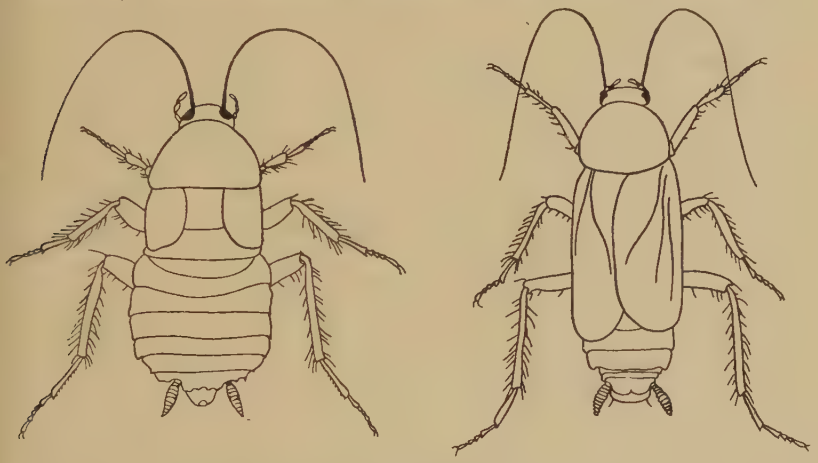

FIG. 85.—*Blatta orientalis.* Left, female. Right, male. × about 2. (After Kükenthal.)

a foreigner to this country, it might almost be called the "English cockroach." The sexes pair during the summer months—April to September—and about a week later the first of many egg-capsules is produced. The egg-capsules are dropped by the female and the ten or twelve young hatch, at once beginning an independent existence. At first, and after each successive moult, the organism is colourless, the rich brown colour being assumed after about three days. The phase known as the nymph, which precedes that of the imago, is reached in about four years after some four or six moults. After a short period of quiescence the final moult produces the sexually mature insect with the wing condition characteristic of the sex.

Blattella germanica L. is about 12–13 mm. in length. Both sexes have wings covering the abdomen, and the colour is a golden brown with darker markings. In America it goes by the name "croten bug." A severe infestation of this species is more difficult to overcome than one of *Blatta orientalis*. A greater number of eggs is produced, maturity is reached in about five months, or at least within the year, and in addition to this the adults are more active and much more suspicious of poisons and other methods of offence devised by man. One other point of importance is that the female carries the egg-capsule almost until the young are ready to hatch, and in this way damage to the capsule and its contents is less probable. This species is now found in almost all parts of the world. It has a remarkable way of travelling from one building to another in swarms, and it flourishes best at 68° F. in a moist atmosphere. It is probably of Eastern origin. Liquids are described as "an insurmountable barrier."

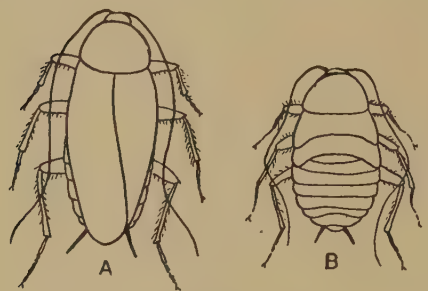

FIG. 86.—*Blattella germanica*. *A*. Female, *B*. nymph. × about 2½. (After Severin.)

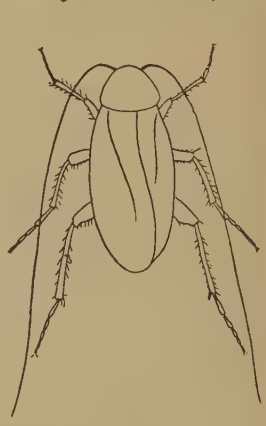

FIG. 87.—*Periplaneta americana*, female. × ½. (After Lefroy.)

Periplaneta americana L. is the largest species, measuring about 30–38 mm. in length. Its native place was probably Central America, but it has spread rapidly and is very abundant in the holds and cooks' galleys in vessels, in boiler-houses, sugar-mills, and breweries. It is of a light brown colour and the wings are large and well developed

in both sexes. The egg-capsules, normally containing sixteen eggs, may be produced about ten days after the last moult. From records taken in Formosa, Takahashi states that a female can produce about fifty egg-capsules during her lifetime, dropping one every 3–7 days. The incubation period is 19–70 days, according to the circumstances. The stages from the egg to the adult occupy 8–19 months, and during that time there are six or seven moults. The female has an average life of seventeen months, while in the male the average length of life is said to be only seven months.

The Control of Cockroaches

This is a difficult question, and patience and persistence are required. All species are more or less quick to detect and avoid poisoned food. Insect powders are of use if put down at dusk and used regularly. Various recipes are recommended :

1. 4 pints commercial grade of finely powdered sodium fluoride, 1 pint powdered borax.
2. 3 pints sodium fluoride, 1 pint pyrethrum powder.
3. Powdered borax alone.

Pastes of different kinds are used, e.g. borax and syrup. Phosphorus paste is also effectual, but this must be used with care when pets are kept. Traps are serviceable, but *Blattella germanica* is difficult to catch in this way because of its small size and light weight. Fumigation is very efficacious, but not by any means always possible. A mixture used on board ship with great success was 4 oz. sodium cyanide, 17 oz. hydrochloric acid, and 3 oz. sodium chlorate to 1,000 cubic feet with an exposure of two hours, repeated after about fourteen days. Carbon bisulphide 2 lb. to 1,000 cubic feet with an exposure of thirty-six hours is useful. But in both cases fumigation should be conducted by experts, as these fumigants are very dangerous in the hands of the inexperienced. A badly infested place should be carefully examined and all cracks in brickwork or irregularities in corners filled

in to prevent lodging-places for the egg-capsules and to render the place more easily cleaned.

Family Gryllidæ

Mention must be made of the house-crickets, though they are of little economic importance.

Gryllus domesticus measures about 25–30 mm. in length, and is light brown in colour. The back legs are long and modified for jumping. In the males the fore-wings are fairly heavy and across the anterior end is a curved file-like ridge. When the wings are moved on one another, the files come into contact and the characteristic shrill noise is produced. The flight wings though large are little used and are folded

Fig. 88.—*Gryllus domesticus*. The house-cricket. × 2. (After Lefroy.)

both longitudinally and transversely when at rest. Crickets are queer, grotesque creatures—often heard but seldom seen. There are few records of damage done by them, but in one case they made their way from a neighbouring bakery to a drapery stores in Paris and much damage was reported amongst the woollen and silk goods—the cottons were left untouched. In the eighteenth Report of the State Entomologist of Connecticut the following recipes are given for poison baits :

1. ½ lb. potato flour, ½ lb. borax, 1 mashed ripe banana, mixed with water till a thin paste.

2. 1 tablet of bichloride of mercury, ½ cup of water, 1 cupful of flour, 1 chopped skin of a banana, mixed to make a paste.

The pastes are spread on cards and left in the rooms where the crickets can get at them.

Order PSOCOPTERA

Mostly small soft-bodied insects, white or greyish-white in colour, few cross-veins, the others remarkably prominent, fore-wings large and when at rest folded over the body in a roof-like manner. Long filiform antennæ. Biting mouth-parts (hence the old name of the Order Corrodentia). Little known about metamorphosis, but probably incomplete.

This Order includes some small but interesting insects. They cannot be classed amongst the injurious insects, but by their presence in large numbers they have been known to cause great damage and considerable inconvenience. Certain forms are wingless and are found in grain, associated with other insects, and also in corks, books, straw, etc. The two genera found in such localities are *Atropos* and *Cœcilius*.

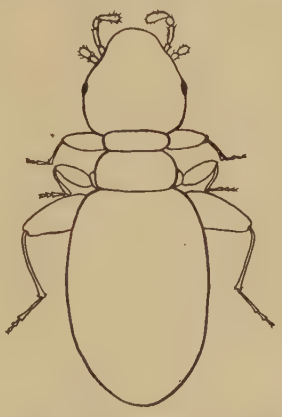

Fig. 89.—*Atropos divinatoria*, dorsal view. The "book-louse." × 48.

Atropos divinatoria L. is commonly known as the book-louse, for it is to be found in old libraries amongst books and papers that are little used. It is about a sixteenth of an inch in length, and in spite of its wingless condition, it spreads from place to place, and is often found in great numbers. Book-lice have a peculiarly hesitating mode of progression that is quite characteristic, and as they run along the book-shelves and furniture they can be recognised at once. Another point of interest is the tapping noise which these insects produce. This is said to be made by the lacinia or inner lobe of the maxilla. This is modified to form a " pick " articulating with the outer lobe like a piston sliding to and fro in its cylinder, and tapping the surface on which the organism rests.

These insects do not attack man and there is no record of their bringing any harm to man.

Cœcilius pedicularius, a winged Psocid, has been recorded in upholstered furniture and mattresses, and in one case considerable difficulty was experienced in ridding a mattress factory from the attacks of this insect. From the evidence, it would seem that the outbreak was caused by the use of straw that was already contaminated. The

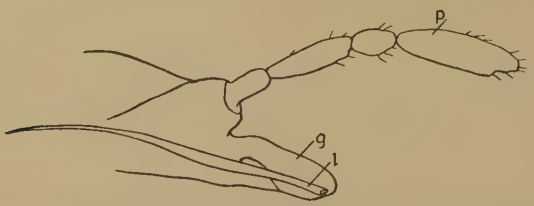

FIG. 90.—Camera lucida drawing of the first maxilla of *Atropos divinatoria*, the "book-louse," showing the lacinia with which the tapping noise is made. × 225. *g.* Galea, *l.* lacinia, *p.* palp.

Psocids, present in large numbers, were seen flying in thick clouds when the doors of the mattress-rooms were opened in the morning.

CONTROL.—The method for destroying the pests was as follows. First the rooms were fumigated with rock-sulphur with the doors, etc., sealed for twenty-four hours. The floors were then scrubbed with water and carbolic soap and the walls washed with a mixture to which carbolic acid had been added. The process was repeated after some days and there was no further trouble.

CHAPTER IX

ORDER LEPIDOPTERA

1. The four wings are all used for flight ; they are membranous and covered with overlapping scales, which are modified hairs. In the more primitive members of the group they are scattered irregularly over the wings, but in the higher types they are in regular rows. There are few cross-veins. The scales are found also on the body and legs.

2. The mouth-parts are modified for sucking, the fused maxillæ form a long tube up which the food is drawn. The tips of the maxillæ are sometimes provided with spines used to lacerate the plants and so free the juices. The adults of some species never eat.

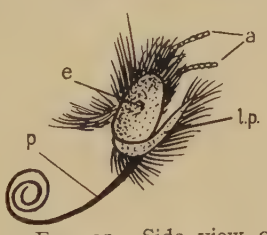

Fig. 91.—Side view of the head of a butterfly. *a.* antenna ; *e.* eye ; *l.p.* labial palp ; *p.* proboscis.

3. Metamorphosis is complete. The larvæ are commonly known as caterpillars, usually cylindrical in form with three pairs of true thoracic legs and 1–5 pairs of pseudopods on the abdomen. They are mostly herbivorous. In many cases when full-fed they spin a cocoon of silken threads. The pupæ are of the obtecta type with the appendages pressed against the body.

The Order Lepidoptera is a large and important one, but it is with only four families that we are concerned, and these all belong to the Heterocera, a series which includes the moths. These members of the Lepidoptera rarely possess clubbed antennæ. They are mostly night fliers. The wings, when at rest, are either wrapped round the body, spread horizontally, or held in the form of a

pent-house over the body. The four families mentioned here are the Bombycidæ or true silkworm moths, the Saturniidæ or wild silkworm moths, and the Pyralidæ on account of *Ephestia kühniella* and the Tineidæ for the so-called clothes moths.

Family Bombycidæ

Small dull-coloured moths, without proboscis or frenulum. About 100 species. Larvæ with five pairs of prolegs and with few hairs.

Bombyx mori L.—The silkworm moth is indigenous to Asia, where it has been domesticated for many hundreds of years. It was introduced into Europe some time in the sixth century and is no longer found wild. It is now reared in France and Italy. In different parts of Asia, China, Japan, and various districts in the Mediterranean countries and in India the silk produced shows considerable variations in colour and texture, and this is not wholly dependent upon the food supplied to the larvæ. The European races are all univoltine, i.e. producing one generation a season and one crop of silk a year. The Asiatic races are multivoltine, of more speedy development, giving three or four broods a season, but with the disadvantage that the silk is inferior to that of the European races both in quantity and quality. Experiments in hybridisation are being made in the endeavour to produce a race combining the multivoltine character with the high qualities of the silk of the univoltine races. At Pusa such a hybrid strain has been taken to the forty-second generation, and it is stated that the silk is 36 per cent. better than that produced by the indigenous race. From a recent record it would seem that Nature herself had solved the problem in the case of certain varieties introduced into Madagascar. These were all univoltine and retained that character for two years, but are now producing six generations a season and spinning silk of the first quality. The eggs hatch out only 12–13 days after laying instead of requiring the period of hibernation characteristic

of their univoltine ancestors. However, it is an undoubted fact that sericiculture is a steadily declining industry, for it can only be carried on with profit when labour is cheap and plentiful and when the workers begin quite young and early accustom themselves to the handling of the delicate cocoons. The reduction of the world supply of natural silk is largely compensated for by the increased production of artificial silk.

The imago of *Bombyx mori* is a small moth of a creamy-grey colour, with two or three more or less distinct brownish lines across the fore wings. The head is small and the abdomen and thorax are densely covered with hairs and scales. It is a rather feeble moth and, having no proboscis, takes no food. The sexes meet immediately after emergence and the moths live for only a few days. The length of life is extended should the conditions show an increase in humidity. There seems to be more infertility amongst European and hybrid strains, but it is possible to overcome this in some measure by feeding the larvæ with mature foliage only. The eggs are yellow and, in the univoltine races, are laid in August and September. One individual can lay 400 eggs. These are known as "seed," and 1 oz. of seed contains 30,000–55,000 eggs. The eggs are carefully stored during the winter months at an even temperature and in May they hatch, producing small caterpillars which must be provided with plenty of food. For this purpose the white mulberry is generally used, *Morus alba*. The silk rearer has, of course, taken the precaution to provide a mulberry plantation of a suitable size, well stocked with healthy trees, carefully pruned, and supplying the finest foliage. The leaves of other plants cause the production of silk varying in colour and quality. It is recorded that by adding tannin to the mulberry leaves the silk is more elastic. The larvæ are grey when hatched and have long stiff hairs ; as growth proceeds they become light in colour and the hairs inconspicuous. The larvæ are generally kept on large wicker trays and tended at suitable intervals, supplied with fresh leaves and the debris removed. As growth proceeds some have to be

moved to other trays. The following table will illustrate the amount of space required :

1 oz. of seed after the	1st	moult	requires	1	sq.	metre.
1 „	„	„	2nd	„	„	3	sq. metres.
1 „	„	„	3rd	„	„	9	„
1 „	„	„	4th	„	„	22	„
1 „	„	before spinning			„	60	„

When full-fed, the larvæ become quiescent and after a time begin to spin the cocoons. The silk is the secretion from the salivary glands. These open by two apertures in the apex of the lower lip. The thick gummy fluid, varying in colour according to circumstances, hardens on exposure to the air. The larva spins its cocoon, beginning at the outside and working inwards, forming a continuous thread of silk. Should the larva be lying in an irregular space, the outer layers will be in short lengths ; but the inner layers are of one thread, wound regularly round and round, sometimes measuring 300 yards. The thread consists of a central core of fibroin coated with sericin or silk-albumen. When spinning has ceased, the cocoons are sorted and certain of them are allowed to produce moths which will lay eggs for the production of the next generation. Those cocoons reserved for the silk are watched and at the appropriate time the pupæ within are killed by the action of hot air. Should this be delayed, the moths will emerge, breaking the once continuous threads into countless short lengths. The silk is wound off on to reels after a preliminary softening of the cocoons in hot water. With the improved machinery for spinning it is now possible to make use of all the silk, even that in short lengths after the emergence of the imago.

Silkworms are subject to many diseases. Grasserie is a form of dropsy brought on by cold damp air and by feeding on damp leaves. Paillot proves that the causative organism can pass from the larva to the adult and from the adult to the eggs. Flacherie is an intestinal disease of the cholera type, highly contagious. Muscadine is caused by the attacks of *Botrytis bassina*. Pebrine is the silkworm disease studied by Pasteur, who showed it to be

the result of an infection by a sporozoon now called *Nosema bombycis*, in the Order Microsporidia. The eggs and sperms of the silkworms are free from infection even though the genitalia producing them are diseased. The young larvæ are readily infected, but can withstand the attacks if they can reach the third moult. The spores of *Nosema bombycis*, taken into the alimentary canal of the young larvæ with the food, give rise to amœboid cells about ·002 mm. in diameter ; these penetrate the cells of the gut, where they develop and give rise to numerous schizonts, which in their turn infect other host cells. In this way the tissues of the larvæ are broken down, and just at the time the grower is hoping for spinning to begin the larvæ shrivel and die. A beetle, *Dermestes vulpinus*, is also an enemy of silkworm larvæ.

Family Saturniidæ—The Wild Silk-moths

No proboscis or frenulum, both pairs of wings with transparent areas. A large cosmopolitan Family with one British species.

Included in the Family are many moths whose larvæ spin silken cocoons, and these vary from a loose network of threads to a closely wound dense mass of silk. Some of the adults are very large, the Atlas moth having a wing-span of 10 inches. None of them feed, and they have no probosces. They are short-lived, nocturnal in habit, and are heavy, sluggish creatures. They lay great numbers of large round eggs which they leave adhering in masses, by means of gum, to the foliage of forest trees. The larva, when hatched, eats voraciously, flourishing only in damp forest in places sheltered from the hot dry winds, often of very local distribution and mostly defying cultivation. Cultivation may be carried on as a subsidiary source of income in the household of the wage-earner, but, except under special circumstances, it is not lucrative enough to be the only income. The silk of several genera and species of wild silk-moths is collected ; some is used locally, while some is an important export. Among the

Asiatic species special mention may be made of the following :

Attacus cynthia produces the Eri silk of Assam. This moth is cultivated on castor-oil plants where the climate is moist and warm. It is quite a usual cottage industry in certain districts, the simple native loom and spinning machine being used for both cotton and silk fibres. As this silk is spun, not reeled, there is no wastage. Eri silk is used locally and little is exported.

FIG. 92.—*Attacus cynthia.* The Eri silk-moth. × ½. (After Lefroy and Ghosh.)

Antheræa paphia occurs wild in India, China, and Japan, feeding on trees and bushes in the open ; the larva is called the Tasar silkworm and the silk is known as Tussar. There are several varieties, some univoltine, others multivoltine. The cocoons are collected and reeled, or it may be that the larvæ are placed on trees and pupation takes place under the watchful eye of the collector. It is well known that silk from reared moths is of poor quality.

FIG. 93.—The full-fed larva of the Eri silk-moth (the spotted form). × ½. (After Lefroy and Ghosh.)

FIG. 94.—The pupa of the Eri silk-moth. × ⅔. (After Lefroy and Ghosh.)

Antheræa assama is a semi-domesticated species of Bengal and Assam producing Muga silk, used locally. The eggs are hatched indoors and the larvæ placed on laurel bushes. If not full-fed when their first bush is stripped, they are transferred to a second and then placed on dry leaves ready for pupation. The seed

cocoons are allowed to remain, while the others are treated with hot air and the silk reeled.

Antheræa peryni, the Chinese oak silk-worm, spins the Shantung silk or Chinese Tussar. It is extensively reared in China, producing a spring and autumn crop ; the latter is the heavier but is of an inferior quality.

Antheræa yama-mai has been called the Japanese counterpart of *A. peryni*. Its larva also feeds on the oak, and the silk obtained from the univoltine race is pale green in colour and is reserved for the use of the Royal House of Japan.

The Western Hemisphere produces *Telea polyphemus* of North America and *Attacus hesperus* of Trinidad, while among the several wild silk-moths of Africa the univoltine *Anaphæ infracta* is of greatest importance.

Family Pyralidæ

This is a large Family of small moths of many species, having in common certain highly technical characters in connection with the veining of the wings which are scarcely within the scope of this book. The adults are possessed of long probosces, the larvæ have ten prolegs and a few scattered hairs. This Family includes several moths found in flour, biscuits, oatmeal, etc. The most serious offenders are *Ephestia kühniella*, *Pyralis farinalis*, and *Corcyra cephalonica*. As the first is by far the most common, a detailed description is given.

Ephestia kühniella Zel., frequently known as the Mediterranean flour-moth, was responsible for a considerable amount of damage to biscuits used as rations during the Great War. In all probability the " worms " found by the troops in the biscuits during the Napoleonic Wars were the larvæ of this species. Although

Fig. 95.—*Ephestia kühniella*. The flour-moth. × 3. (After Durrant and Beveridge.)

there are many records of this moth from the Mediterranean, it would seem there is no evidence of this being its place of origin and therefore the name is misleading. It can only be said that *Ephestia kühniella* is now cosmopolitan and that the original locality is not known. The moth has a wing-span of $\frac{3}{4}$–1 inch, its length is about $\frac{1}{2}$–$\frac{3}{4}$ inch when at rest. The wings fold over the body penthouse-like and the posterior end of the abdomen is turned up between them. The fore wings are dark grey and the silvery hind wings are outlined with long hairs. The flight is slow and heavy, rather aimless in character, but often prolonged for some distance. The moths fly either by day or night, but are never found in draughty places. The length of life of the adult female is about a month. The eggs are laid during the latter part of this time. They are minute, ·58 mm. × ·38 mm. They are deposited singly, as far from the light as possible, generally in the foodstuffs, but sometimes at some distance from the food. On hatching, the larva either begins to feed voraciously or hurries off in search of food, which, when found, it devours steadily until full-fed. In either case it spins for itself a silken tube in which it lives. When full-fed this is discarded, the larva seeking a suitable dark place in which to pupate. As it passes through the flour to its favourite place, the creases near the ears of the sack, it leaves threads in its path causing the " webbing " so characteristic of the attacks of this organism. This " webbing " is found in the sack or in the shafts or flues of the warehouse. The larvæ of *Ephestia kühniella* are found not only in flour but in starchy foods of all kinds, grains already attacked by beetles, dried vegetables, cocoa-beans, nuts, jellies, and chocolate powders.

FIG. 96.—*Ephestia kühniella*, larva. (After Durrant and Beveridge.)

The place of pupation having been successfully reached, the larva, after a few days, proceeds to pupate, spinning a cocoon matted with flour in which it lies ventral side

uppermost. Stringer gives the following table as indicating the average duration of the life-cycle.

Egg to larva	14 days.
Larva to pupa	128 ,,
Pupa to imago	16 ,,
Egg to imago	158 ,,

In warm climates the life-cycle is carried through much more quickly, and the converse is true when the temperature is low. In the east there are often four broods a year, or breeding may go on all the year round.

The damage done by this insect has been indicated. Flour is contaminated by webbing and fæcal matter,

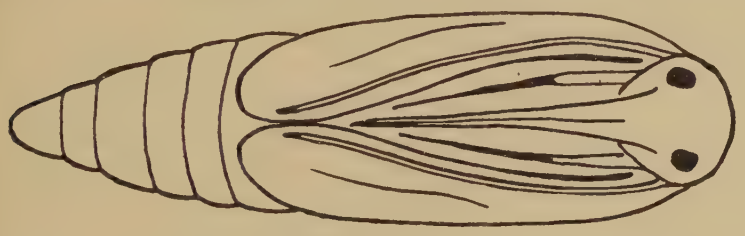

Fig. 97.—*Ephestia kühniella*, pupa.

biscuits are devoured, and flour-mills rendered highly infectious.

Control.—The oldest method of combating the attacks of this insect is the use of heat ; 140° F. for ¼ hour kills all eggs, larvæ, and adults. This heat should be caused to penetrate to the centre of the flour-sack or mass of flour. It has been shown that cold does nothing more than delay the development of the eggs and larvæ ; it does not kill them. Investigations have proved that during the cooling process, after biscuits were cooked and before they were sealed in tins, contamination could take place. It was therefore suggested " that the temperature conditions during cooling should be rendered as uncomfortable as possible for the moths by introducing screened air which should be continuously withdrawn by revolving fans, suction, or some similar contrivance." This is based on the fact that the moths dislike air that is rapidly moving and therefore do not oviposit under

such conditions. Fumigation with various substances has proved of use. Hydrocyanic acid gas has been used in mills, milling being suspended. Sulphur dioxide is efficacious, but it destroys the flour for human use. The mills must therefore be emptied before the gas is pumped in.

Family Tineidæ

This Family includes many hundreds of small moths, with two pairs of narrow wings with wide fringes. The larvæ of many of the species are vegetable feeders ; a few feed on dead animal matter and some are predaceous.

Tinea pellionella L.—The Case-making Clothes Moth, or the Single-spotted Clothes Moth.

This is one of the most dreaded insects in the household and its distribution is almost world-wide, as it is found in Europe, North and South America, West and Central Asia, Ceylon, Japan, Australia, and New Zealand. The moth is greyish yellow in colour and has a wing-span of about ½ inch. In cooler climates the moths are most prevalent in June, July, and August, but when conditions are more favourable they breed without cessation and the moths, recognisable by their irregular hesitating flight, can be seen at any time of year. The female deposits her minute whitish eggs on woollen goods of all kinds, furs, silks, and feathers, i.e. on substances of animal origin. Under normal conditions the larva hatches in about ten days. It is white with a brown head and neck. It begins to feed at once and makes for itself a case in which it lives. This is a tubular structure, lined with fine silken threads, the outside strengthened with small portions of the material

Fig. 98.—*Tinea pellionella.* The case-making clothes moth. × 3·5. (After Howard and Marlatt.)

on which the organism is living. The case is open at both ends and the head and thorax are thrust out when the larva feeds or moves. As the larva grows so the case is increased in length by the addition of material at either end, and an increase in diameter is accomplished by the insertion of gussets. Should the larva be transferred from one coloured material to another, the case will be of similarly differing hues, a case of many colours. In northern latitudes during the autumn the larva prepares for hibernation by withdrawing itself into the case and remaining quiescent. In the late spring pupation takes place. After about three weeks the pupa wriggles out of the case and the moth will then emerge.

Tineola biselliella Hum.—The Webbing Clothes Moth or the Naked Clothes Moth.

The webbing clothes moth has almost a world-wide distribution, though this has probably been brought about by man. It is found in Europe, North America, North Africa, Australia, New Zealand, and India. In northern latitudes it seems to be more common than the case-making moth. It can be distinguished from this organism by its rather larger size and by the absence of spots on the fore wings. The adults emerge from the cocoon in June and July and the sexes meet immediately. The length of life of the male is about fourteen days and that of the female about eight days. At 20–25° C. (68–77° F.) oviposition takes place about twenty-four hours after copulation. About 60–90 eggs are laid over a period of 2–3 weeks. Scanty feeding by the larva produces a moth which lays less than the normal number of eggs. The larva spins silk wherever it goes, hence its name. The larval life

FIG. 99.—*Tineola biselliella.* The webbing clothes moth. × 6. (After Howard and Marlatt.)

extends over 10–12 weeks, depending on the temperature, and as many as seventeen moults have been observed during that time. The pupal stage, which is passed in a cocoon of silk and wool, lasts about two weeks and the average life of the adult female is about thirty days. The larva of this species has the power of fasting for considerable periods and then taking up its life as if nothing had happened when conditions are once more favourable.

Trichophaga tapetzella L.—The Tapestry Moth or Black-cloaked Moth.

This moth is larger than either of those just described. It has a wing-span of ¾ inch. It is rarer and not so widely distributed. The proximal half of the fore wings is black, while the rest is a creamy grey. When the wings are at rest, the moth has the appearance of wearing a black cape. The larva of this species seems to be a coarser feeder and it is found burrowing into carpets, tapestries, felting, skins, and thick woollens, making tunnels lined with a soft silk. The larva is full grown when about 10 mm. in length. Pupation takes place in a silken cocoon inside the tunnel.

FIG. 100.—*Trichophaga tapetzella*. The tapestry clothes moth. × 5. (After Howard and Marlatt.)

THE CONTROL OF CLOTHES MOTHS

Many useless remedies are recommended for the combating of the attacks of clothes moths, and this has led to the somewhat exaggerated idea of their powers of doing damage. As with other things, "prevention is better than cure," and there are several very efficacious methods for preventing the initial attack. Woollens, silks, and fur should be stored in sealed paper wrappings, and if these bags are made of newspaper the printer's ink will act as an additional deterrent. Cold storage

is the surest of all preventives and is now much used. Naphthalene or paradichlorobenzene may be packed with the clothing, but these are not always effective, and as both substances evaporate they require replacing frequently. Stored clothing packed in drawers with these chemicals should be brushed and shaken in the sunshine at intervals of three or four weeks. To turn to the more serious problem of combating an attack, fumigation with hydrocyanic acid gas brings certain death to all stages, eggs, larvæ and pupæ, and moths ; but this should only be carried out by an expert, because of the danger to human life. Carbon bisulphide is also good as a fumigant but dangerously inflammable. Sulphur must be used with care because of its bleaching effect upon some of the more delicate textiles. Dry heat of 130° F. is destructive to all stages, while water of 140° F. will also kill all stages.

Experiments have been made recently with various "moth-proofing solutions," and success has been achieved with neutral solutions containing silicofluoride of sodium, potassium, lithium, zinc, or aluminium, and also by using solutions of fluorides and silicofluorides with sulphates of some metals acidified by the addition of an organic acid such as oxalic, tartaric, or acetic.

CHAPTER X

INSECTA

Order COLEOPTERA

The mesothoracic wings are in the form of elytra ; when at rest they are turned back, fitting closely together in the middle line and concealing the membranous flight wings of the metathorax which are folded underneath them. This gives an appearance of the complete absence of wings, for they are not seen except when the insect is in flight. The mouth-parts are used for biting ; the mandibles are sometimes very conspicuous. Metamorphosis is complete.

This is a very large Order containing many remarkable types. In a book of this kind details of classification cannot be given and no attempt is made to give the diagnostic characters of even the families. The following species are described because of their connection with the food and possessions of man.

Family	
Cucujidæ .	*Silvanus surinamensis* L. Saw-toothed grain beetle.
	Læmophlæus pusillus Sch.
Bruchidæ .	*Bruchus pisorum* L. " Pea weevil."
	Bruchus obtectus Say. " Bean weevil."
Curculionidæ	*Calandra granaria* L. Granary weevil. Black weevil.
	Calandra oryzæ L. Rice weevil. Spotted weevil.
Bostrichidæ .	*Rhizopertha dominica* Fb.
Ptinidæ .	*Ptinus fur* L. White-marked spider beetle.
	Anobium paniceum L. " Biscuit weevil."
	Anobium punctatum De Geer. Common furniture beetle.
	Xestobium rufovillosum De Geer. Death-watch beetle.

Family.	
Lyctidæ .	*Lyctus brunneus* Steph. } Powder-post *Lyctus linearis* Goeze. } beetles.
Dermestidæ .	*Dermestes lardarius* L. Larder beetle. *Dermestes vulpinus* F. Silkworm parasite. *Trogoderma granarium* Everts. *Anthrenus scrophulariæ* L. Carpet beetle.
Tenebrionidæ	*Tenebrio molitor* L. Yellow mealworm beetle. *Tribolium castaneum* Hbst. Red grain beetle. *Gnathocerus cornutus* Fabr. Broad-horned flour beetle.

Family Cucujidæ

Silvanus surinamensis (L.)—Saw-toothed Grain Beetle.

This is one of the smallest beetles found habitually in groceries, and certainly it is the one found most frequently in pantries and wherever food is stored. It is usually said to be a vegetable feeder, but it is really omnivorous. Dendy has shown that although found in cereals, it is to be looked upon only as a secondary grain pest, as it is incapable of piercing healthy seed-grains. It is also found in bread-stuffs, preserved fruits, nuts, and seeds of many kinds, in yeast, cakes, mace, snuff, and even in red pepper. Records have been made of these beetles feeding on sugar, starch, tobacco, and dried meats, but though the imagines may live on such substances, it is improbable that they could breed there.

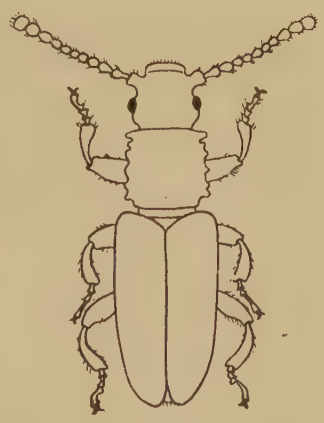

Fig. 101.—*Silvanus surinamensis*. The saw-toothed grain beetle. × 22.

Silvanus surinamensis is a very small beetle, 2·8 mm. long, slender, flattened, and of a chocolate-brown colour.

It derives its name from the fact that the lower borders of the thorax are toothed, having six teeth on each side. The dorsal surface of the thorax shows two shallow longitudinal grooves; the antennæ are characteristically clubbed. The larva is slender and depressed dorso-ventrally; it is nearly white in colour with a dark mark on the dorsal side of each segment. There is one pair of abdominal prolegs. The pupal case appears to be made only when the larva is feeding on coarse foods; it then consists of various fragments cemented together. If the larva is in flour or meal there appears to be no pupal case at all, the larva merely attaching itself to some convenient surface and passing into the pupal state with no further protection. The life-cycle is complete in twenty-four days during the summer months, but in the spring this period is sometimes extended to six or eight weeks.

Læmophlæus pusillus

Læmophlæus pusillus is also one of the secondary grain pests, for like *Silvanus surinamensis* it does not seem to be able to make the initial attack on sound grain. It is nearly always found in conjunction with *Tribolium castaneum*, a grain pest of first importance, which pierces the pericarp and so enables *Læmophlæus pusillus* to reach the endosperm.

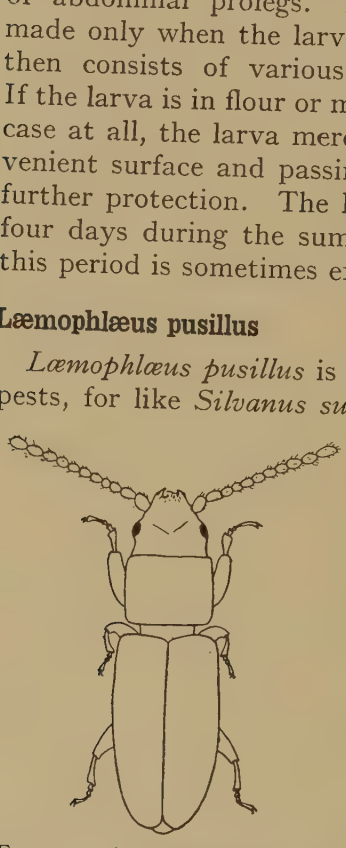

FIG. 102.—*Læmophlæus pusillus*. × 27.

The egg is small and cylindrical in shape, rounded at both ends, white, translucent, and ·6 mm. long. The larva when newly hatched is ·7 mm. in length and yellowish white, while the head and spiny anal appendages are reddish. The larva is thickest at the middle of its length and tapers towards the head and tail. This rather characteristic shape changes when the larva is full grown,

the head and thorax being wide posteriorly. There are four moults and the last reveals the pupal stage. The pupa is small, being only 1·75 mm. in length, and it has a peculiar contracted appearance. The imago is a small beetle 2 mm. long, flattened, brown in colour, and with filiform antennæ. The life-cycle is complete in 36–75 days, depending on the temperature, and the length of life of the adult appears to be two or three months. From observation it would appear that copulation takes place 5–7 times.

Family Bruchidæ—Pulse Beetles

This Family includes many small beetles whose larvæ are frequently found in the seeds of leguminous plants. Some are found only on plants in fields, others are able to breed for generation after generation either in store-houses amongst the stored seeds or on the growing plants. It is estimated that damage amounting to some thousands of pounds a year is done to stored crops by these pests. The Bruchidæ are characterised by having the head prolonged anteriorly into a broad beak, and so they have received the name of weevils, which is misleading as this is applied to the Curculionidæ, the Family including the true weevils. The wing-cases are short, and the posterior end of the abdomen is exposed. The most important genus of this family is Bruchus, and there are many species which do damage to crops.

Bruchus pisorum (L.). Pea weevil.
,, *obtectus* (Say). Bean weevil.
,, *chinensis* (L.). Cowpea weevil.
,, *quadrimaculatus* (Fabricius). Four-spotted bean weevil.
,, *rufimanus* (Bohemen). Broad-bean weevil.
,, *lentis* (Bohemen). Lentil weevil.

Bruchus pisorum is a typical example of this genus. The adult is a small brownish-grey beetle 5·8 mm. long, with black-and-white markings on the wing-covers. It

is not very common in northern latitudes, where it produces only one generation a year. The adult hibernates during the winter in the peas and the eggs are laid upon the pod. These are yellow, spindle-shaped, and 1·2 mm. long. They are deposited singly and attached to the outer surface of the pod by a viscid secretion. The larva is a white fleshy grub, 6 mm. in length, and much wrinkled. It bores through the pod in order to reach the young peas inside, and then it attacks them and feeds on them—curiously enough, it does not destroy their power of germination. Usually only one larva is to be found in each pea. The pupa is whitish, gradually turning brown towards the end of the pupal stage, and after about a week the adult will emerge. The adult only oviposits on dry peas.

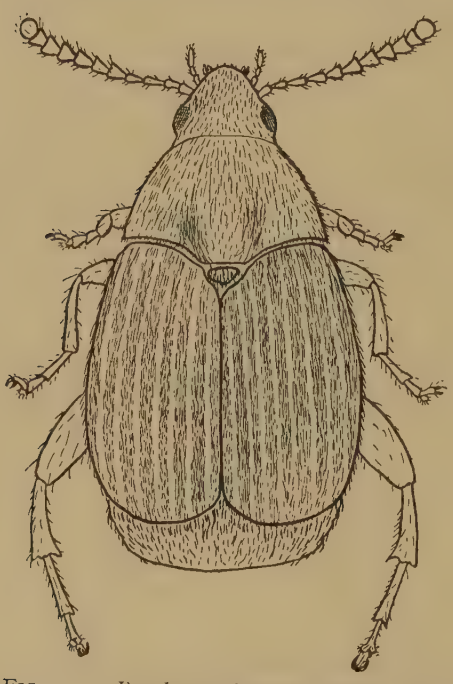

FIG. 103.—*Bruchus rufimanus*, imago. Pulse beetle. ×18. (From a culture in French beans.)

CONTROL.—The following interesting method has been devised by means of which clean peas may be separated from those infested with *B. pisorum*. After harvesting, the peas are immersed in a concentrated solution of salt, with a specific gravity higher than that of the seriously damaged peas, in order that the latter may be able to rise to the surface. For the larger varieties of pea, Chile saltpetre is used, as a solution of high specific gravity may thus be obtained. The peas sorted in this way are then

washed free of the salt or saltpetre and dried, while the waste liquid is utilised as manure.

Bruchus obtectus is very like *B. pisorum*, but slightly smaller, since it measures 4·4 mm. in length; its marking is less noticeable than that of *B. pisorum*, because it is covered with hairs which give it a brownish-olive appearance. In this case the adult female bites a hole in the pod in which she deposits her eggs, in or on the bean. She also is able to oviposit only on dry beans, and successive generations are developed in stored beans during the year. Sometimes as many as twenty-eight larvæ may be found in a single seed (cf. the solitary larva of *B. pisorum*). A generation usually requires 21–80 days to develop—i.e. in warmer climates the time is shorter, and the number of generations greater, with a corresponding increase in the amount of damage done.

FIG. 104.—Larva of *Bruchus rufimanus*. × 14.

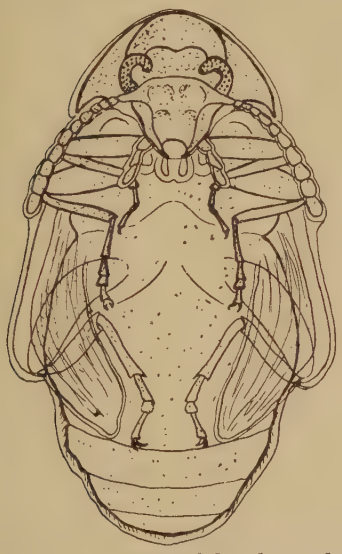

FIG. 105.—Pupa of *Bruchus rufimanus*. × 18.

Bruchus rufimanus is a closely allied species found in French and broad beans.

Family CURCULIONIDÆ—The True Weevils

Antennæ straight or elbowed and always clubbed. Beak variable in length.

This is a very large Family, including more than 20,000 species. Most species are found on plants and no part of the plant seems to be immune from their attack. The two species described here belong to the genus Calandra (Clairv.) = a kind of lark. They are *Calandra granaria*,

commonly known as the granary weevil, and the other *Calandra oryzæ*, the rice weevil. The Sub-family of Calandrinæ to which they belong is often called the family of the " bill-bugs " or " elephant beetles." They have been known to attack stored grain from the earliest times, in fact they are the first beetles to be recorded.

Calandra granaria L.—The Granary Weevil.

The granary weevil is cosmopolitan and is found wherever grain is stored. It seems to be in almost every variety of grain. The adult is a small brown beetle $\frac{1}{8}$–$\frac{1}{16}$ inch in length. The mouth is situated at the end of the long snout, exceedingly well placed for boring into the grains. The germinal spot seems to be the favourite point of attack. The beetle quickly burrows into the grain where it takes shelter. Not only are grains destroyed in this way, but the female bites a hole in other grains in order to deposit her eggs in a safe place. Several eggs may be laid in one grain, but each in a separate hole. A white legless larva hatches from the egg and begins to feed at once on the soft endosperm, each day becoming more shapeless and ungainly. After three moults and when full-fed, the larva changes into a white pupa and in 5–16 days, depending upon the temperature, the adult emerges. The complete life-history takes from 30–40 days in summer temperature. The species is wingless and, as its name implies, it is an indoor species found in granaries. Four or five generations are produced in the year and the damage done by this insect is very great. It has been calculated that in America alone it is responsible for 20,000,000 dollars annual loss. The control of *Calandra granaria* has been a matter for experimentation. The problem of stored food will be discussed (see Chapter XIV) later, but here it should be stated that grain stored at a temperature below 6° C. is immune from attack. (This is the natural condition of storage in South Russia.) A moisture content of the air of the storehouse below 12 per cent. is injurious to the beetles. Grain to be used for seed, not for food, may be stored with safety when mixed

with copper carbonate dust in the proportion of 2 oz. to the bushel ; this prevents the feeding of the adults and consequently no eggs are produced.

Calandra oryzæ L.—Rice Weevil.

The " rice " weevil is a native of Asia, found attacking rice, white maize, barley, rye, oats, and buckwheat. The young insect is light brown in colour, but this gradually darkens until in old age the beetle is a dull reddish brown. There are four dark red-brown spots on the elytra which are also marked with longitudinal grooves. The flight wings are well developed, and though in captivity *Calandra oryzæ* is hardly ever seen flying, in its natural surroundings it is an active flyer at night-time. It is by the flight of the adult that the pest is spread from one field to another, for this insect attacks the growing plants as well as the standing grain. The damage wrought by the rice weevil is very extensive.

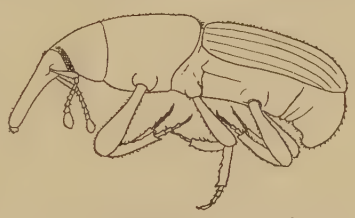

FIG. 106.—*Calandra oryzæ*, imago. The rice weevil. × 14.

The eggs are laid singly in small holes made by the female in the grain. These punctures seem to be made in any part of the grain. Hinds and Turner record that under ordinary circumstances the maximum number of eggs laid in twenty-four hours is twenty. The rate at which they are laid appears to depend on the hardness of the grain, and records of the total number of eggs laid vary very greatly, but the maximum is given as 417 (Hinds and Turner).

With regard to the life-history of the rice weevil records also vary, but Fletcher and Ghosh state that at Pusa during the summer months three generations follow one another in quick succession between August and October, that is, each generation occupies a period of about one month. During the rest of the year—November to July—a single generation may take from one and a half to six months. Normally the adult weevil lives for about five

months, but the results of Dendy and Elkington show that this is a low estimate. Copulation has been observed to take place within twenty-four hours of emergence, and it would seem that it must occur frequently. The female is able to lay eggs until shortly before death. At a minimum temperature of 60–65° F. the eggs hatch and the small, soft, legless grub, yellowish white in colour, begins to feed at once on the endosperm of the grain. Three larval stages have been recorded, all very much alike, the more important changes being the differing proportions of head to body. These stages occur at intervals of three, four, and nine days respectively. There is a pre-pupal stage, and then pupation takes place in the grain where the larva has spent its life. The pupa is of the type characteristic of the family Curculionidæ, and the normal length of the stage is six days, but this varies with temperature and observers record periods of from three to nine days.

FIG. 107. — Larva of *Calandra oryzæ*. × 14.

Family BOSTRICHIDÆ

Rhizopertha dominica

This insect cannot breed in fresh air, but in a granary it is capable of doing more damage in a shorter time than even *Calandra oryzæ*. *Rhizopertha dominica* has been proved to be a serious grain pest in America, and in India also it is found to be a great destructor of stored wheat. The damage is effected by the adults, who completely empty the pericarp of its contents, the grain being reduced to a floury mass, rendered greyish in colour by the mixture of fæcal matter, and scattered on the surface are seen the empty seed-coats, pierced with large, irregularly-shaped holes. The explanation of this is that the beetles thereby prepare a large store of easily accessible food for

FIG. 108.—Pupa of *Calandra oryzæ*. × 18.

the use of the young, until such time as they are able to bore into the grain for themselves. Experiments made by Barnes and Grove show that the newly hatched larvæ are unable to attack sound grains ; but should they obtain access to the grain through some opening in the pericarp, they are able to eat the undisturbed endosperm, though they cannot make the initial attack.

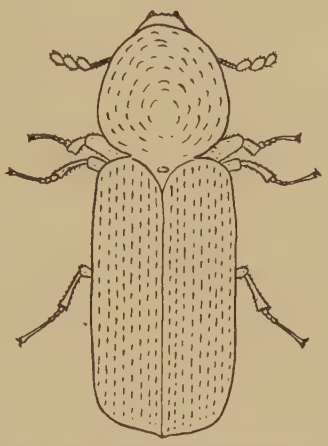

Fig. 109.—*Rhizopertha dominica*, imago. × 21.

Chittenden describes the life-history of this pest. The eggs are " white, elongated, pear-shaped in form, with one end forming a rather narrow stem or neck . . . both ends rounded . . . length ·6 mm., thickest part ·2 mm. diameter." The eggs are laid separately or in clusters ; sometimes many are laid in a day. The insect, though small, lays an extraordinary number of eggs, the average being 300–400, but as many as 586 have been recorded. Copulation appears to take place two or three times in order that all the eggs may be fertilised. These eggs hatch after some days, the time varying according to the temperature—fourteen days April to May (according to Chittenden), five days May to August (according to Barnes and Grove)—that is, the period becomes shorter with an increase in temperature. The larvæ are described by Chittenden as " white, slightly yellowish towards the head ; head yellow, ocelli red-brown, arranged in a triangle ; mouth-parts brown ; antennæ very short ; the head beset with a few long hairs ; legs tolerably long, slightly yellowish with long claws ; each abdominal segment bears a slightly curved, yellow hair, directed

Fig. 110.—Larva of *Rhizopertha dominica*. × 12.

backwards ; length a little less than ·3 mm." The larva generally passes through four moults, when it reaches its full size of about 2·8 mm. Then pupation takes place. The pupa is white when first formed, but later a brown pigmentation is to be observed in the eyes. Pupation takes place in the grain. The adult is about 3·2 mm. long and about ·8 mm. in width ; curiously enough, the external appearance of the male and female is exactly the same, even the antennæ revealing no sexual difference. The length of time required for the development of a generation varies between twenty-four days and fifty-two days, according to the time of year ; there are probably five generations in the year.

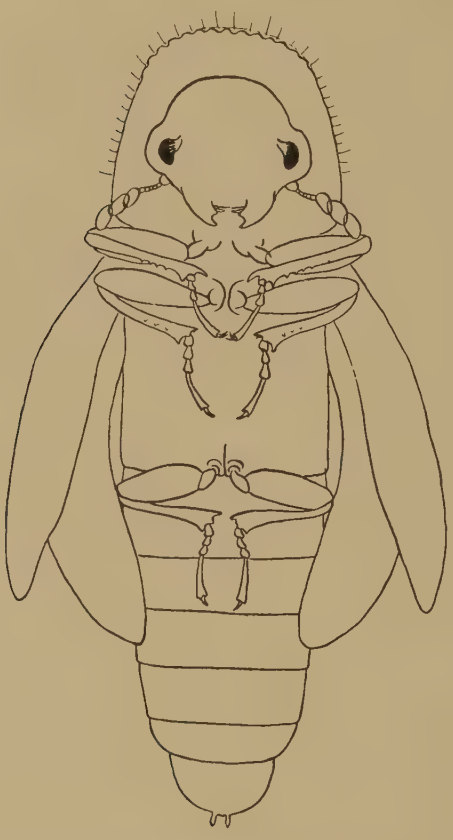

Fig. 111.—Pupa of *Rhizopertha dominica*. × 34.

Family Ptinidæ—The Death-watch Beetles or Drug-store Beetles

The Ptinidæ is a Family of small beetles, $\frac{1}{8}$–$\frac{1}{4}$ inch in length. The tarsi are five-jointed. The head is retractile. The antennæ have 9–11 joints and often bear a three-

jointed club. Many of these beetles are found on dead vegetable matter and in all sorts of stored foods, wood, furniture, dried farinaceous matter, books, drugs of all sorts, tobacco, spices, and pepper. Figs. 112, 113, and 114 are camera lucida drawings of specimens from a culture in cayenne pepper. This strange and undiluted diet seemed to be most acceptable and the culture flourished for some considerable time.

FIG. 112. — *Ptinus sp.?* × 14. (From a culture in cayenne pepper.)

Ptinus fur L.—The White-marked Spider Beetle.

The adult is reddish brown in colour with four white bands on the elytra. It is frequently a serious pest in museums, the larvæ tunnelling into the specimens in the quiet seclusion of the cases.

The genus *Anobium* supplies several species of "furniture beetles," *A. paniceum*, *A. punctatum*, and *A. domesticus*, etc. Here both beetle and larva burrow into the food substance, making neat cylindrical tunnels. *A. paniceum* is also found in biscuits. The eggs are laid in the tunnels and pupation takes place there also. The insects are hardly ever seen; they are most common in May and June. The life-history is only imperfectly known, but it is more than likely that the life-cycle may extend over one, two, or more years.

FIG. 113.—Larva of *Ptinus sp.?* × 14.

FIG. 114.—Pupa of *Ptinus sp.?* × 14.

Xestobium rufovillosum De Geer, The Death-watch Beetle.

The death-watch beetle is of great importance because of the untold damage it has caused to the oak timbering

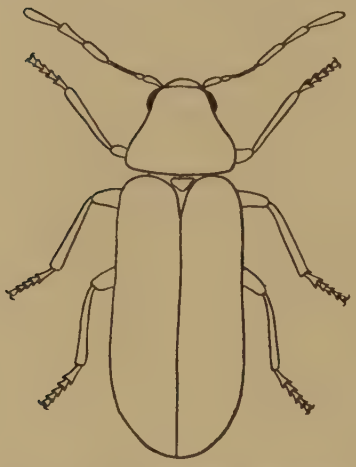

FIG. 115.—*Anobium punctatum.* The common furniture beetle. × 12. (After Gahan.)

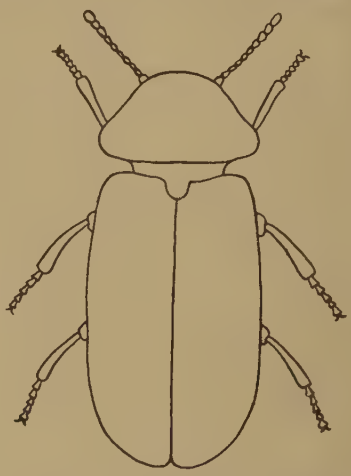

FIG. 116.—*Xestobium rufovillosum.* The death-watch beetle. × 10. (After Lefroy.)

of many of our cathedrals and old buildings. The list of damage is now a long one and it includes such places as St. Paul's and Peterborough Cathedrals and, in Lefroy's own words " probably a very high percentage of buildings which contain oak."

FIG. 117.—Larva of *Xestobium rufovillosum.* × 10. (After Lefroy.)

The beetle appears in April or May and is about 6–9 mm. in length ; it is dark brown with short greyish-yellow hairs arranged in patches. The name " death-watch " has been given to these beetles because of their very characteristic sexual call. This is a tapping noise, of surprising loudness, made by the insect striking its head on the ground. The eggs are about ·6 mm. in diameter. The larva is very like that of the furniture beetles, but when full-fed is

about 9–12 mm. in length. Pupation is thought to take place in the autumn, the pupa lying in a burrow near the surface of the wood. It is probable that the complete life-history takes three years. Most of this time the insect is in the wood in the larval stage and is never seen. In the wild state, that is, on standing trees in the open, there are known to be four beetles which are enemies of the

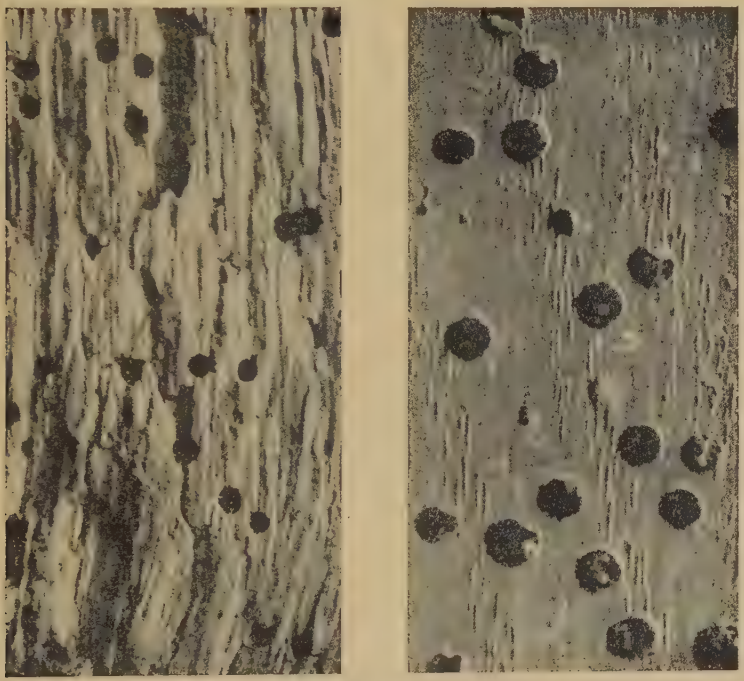

FIG. 118.—Left, the exit holes of the furniture beetle, *Anobium punctatum*. × 2. Right, the exit holes of the death-watch beetle, *Xestobium rufovillosum*. × 2. (By permission of *Country Life*.)

"death-watch" larva; but only in rare cases have these enemies found their way to the timbering in buildings. So the death-watch pursues its course unhindered.

The control of furniture beetles is sometimes a very difficult problem. The adults fly from place to place and lay their eggs in the crevices of the wood; the larva burrows out of sight, and it is not for many months that the possessor of the furniture discovers the attack. How-

ever, the frequent use of a good furniture polish, rich in paraffin oil or turpentine, is the best preventive, for, on wood so treated, the female does not oviposit. In dealing with wood already attacked, the aim is to reach the larvæ and pupæ in the most deeply placed burrows. For this purpose paraffin and turpentine are not sufficient. Dry heat to 131° F. is efficacious. Fumigation with hydrocyanic acid gas, carbon bisulphide, benzene, and carbon tetrachloride kills all stages, but care in the use of these gases is necessary on account of their poisonous or inflammable nature. Liquids, such as benzene and carbon tetrachloride, may be washed over the infected wood or squirted into the worm-holes. It is recommended now that the wood should always be treated before it is used for timbering, etc., and where this has been possible good results have been obtained by the use of creosote under pressure and by painting the wood with the following mixture: 50 per cent. dichlorobenzene, 47 per cent. mineral oil, 3 per cent. barium oleate. The last-named substance is highly toxic to the insects.

Family Lyctidæ—Powder-post Beetles

Small beetles $\frac{1}{8}$–$\frac{1}{5}$ inch in length. Tarsi five-jointed, the last long and bearing a claw. The last two joints of the antennæ are enlarged and club-like.

Lyctus brunneus and **L. linearis**

These two beetles are important pests of the harder woods used in the making of furniture (oak, hickory, and ash), and both species are almost cosmopolitan in their distribution. The beetles are much alike, but *L. linearis* is the smaller of the two and has longitudinal rows of hairs on the wing-cases and a deep elongated depression on the prothorax. The eggs are almost certainly deposited in cracks and irregularities of the wood. The larvæ hatch in about two to three weeks and soon begin to feed and form parallel burrows in the wood. In the spring of the year following that in which the eggs are laid, pupation

takes place in the end of the burrow just under the surface of the wood. After about a month the beetle emerges. Timber may be treated with paraffin wax or varnish or with pure kerosene oil or a mixture of creosote and kerosene, 3 parts to 1 part. These protective washes must be odourless and tasteless where the wood is to be used for storing tea or foods. Fumigation with sulphur dioxide is recommended, and the application of steam under pressure has been successful in killing the insects in all stages. Snyder states that wood submerged in water for four months or wood steamed under pressure for 10–20 hours is immune from attack. He also points out that wood may be stored with safety in a wooden shed when the walls have been creosoted.

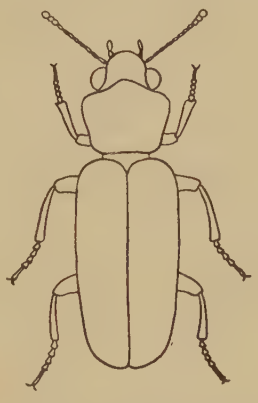

FIG. 119.—*Lyctus brunneus*. The powder-post beetle. × 18. (After Gahan.)

Family DERMESTIDÆ

Tarsi five-jointed. Antennæ clubbed, 11 segments, can be withdrawn into a groove under the head.

A Family of cosmopolitan beetles. Many are vegetable feeders, but some feed on dead animal matter such as skins, horns, wool, meat, cheese.

Dermestes lardarius L.—The Larder Beetle or Ham Beetle.

This is a stout black beetle $\frac{1}{3}$–$\frac{1}{2}$ inch in length, and oval in shape with a band of greyish yellow scales on the proximal half of the wing-covers. The adults appear in May and June and the eggs are laid on the food or in cracks and crevices near it. The larvæ hatch out in about twelve days. They are very characteristic and are possessed of many tufts of long hairs. They quickly begin to feed, tunnelling into the food and pupating there, especially in the fatty regions if the food should be meat.

In temperate climates only one generation is produced in the year. There is an interesting record of this organism found burrowing into the flooring boards of a hide warehouse. The larvæ, dropped when the hides had been removed, had burrowed into the spruce flooring-boards and had, in these unusual surroundings, found sufficient nourishment to complete their life-cycle.

The control of these insects should not be difficult in the ordinary way, as food, meat, and hams can be screened or covered. Fumigation with carbon bisulphide has proved efficacious in killing this insect in all stages. Benzene can be poured into cracks, but care must be taken in case of fire.

Dermestes vulpinus is also found in decaying meat, and it has been found attacking the cocoons of silkworms. By eating through the silk it reaches the pupa, on which it lives. Silk cocoons prepared for travelling have to be carefully packed to guard against attack.

Trogoderma granarium Everts, the Khapra beetle, is a small reddish-coloured organism found most commonly in malthouses, where the temperature reaches 132° F.; but it is also found in Indian barley shipments and in grain from African ports. The adult does not eat. The larva seems to prefer malt and wheat, but it takes rye, oats, rice, and maize and flourishes on them. The insects mate immediately after emergence, and under suitable conditions the female lays about 126 eggs. The larva feeds voraciously on the floury debris and is unable to make the initial attack on the grains. At about the forty-second day after hatching pupation takes place. The larvæ have remarkable powers of resistance and can withstand starvation and lack of air " for years," according to some recorders. The beetles have a curious power of raising the moisture

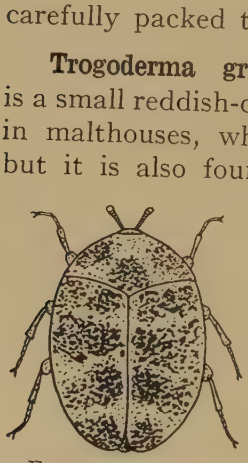

FIG. 120.—*Anthrenus scrophulariæ*. The carpet beetle. × 8. (After Riley.)

content of the storehouse or bin, and this makes the pest more difficult of control and encourages the growth of moulds and mites. Fumigation is the only possible method to use against them, and chloropicrin has been used with success by Mason.

Anthrenus scrophulariæ L.—The Carpet Beetle.

The adult insect is about $\frac{3}{16}$ inch in length and is of a broad heavy build, black in colour with minute black-and-white scales. The English houses, without any central heating, do not offer very comfortable conditions for this insect, but in America towards the autumn the adults appear and, after pairing, lay their eggs away from the light under the carpets. The larvæ hatch in a few days and begin to feed on the underside of the carpets. Furs, feathers, and museum specimens may also harbour these insects. The larva works away under the carpet, and the housewife may one day discover her carpet cut into strips along the lines of the flooring-boards, the grubs having sheltered in the cracks. The skin is cast about six times. The last larval skin is used as the pupal case.

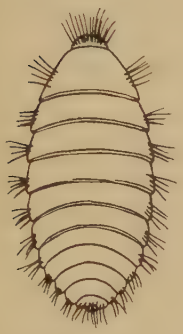

Fig. 121.—Larva of *Anthrenus scrophulariæ*. × 8. (After Riley.)

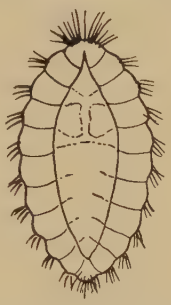

Fig. 122.—Pupa of *Anthrenus scrophulariæ*. × 8. (After Riley.)

The control of this pest should consist mainly of prevention, by more frequent and careful house-cleaning. The carpets should be exposed to the sun and air and sprayed with benzene. The rooms should be swept and the floors washed with water into which carbolic or formalin has been put with the soap. Kerosene or benzene should be poured into the cracks, care being taken against fire. Fumigation with carbon bisulphide or hydrocyanic acid gas is useful but dangerous.

Family Tenebrionidæ—The Darkling Beetles

Mostly black beetles, varying greatly in size and form. The hind tarsi are four-jointed. Wing-covers stiff and hard. Head narrower than prothorax.

Tenebrio molitor L.—The Yellow Mealworm Beetle.

The adult insect is nearly black in colour and flattened in shape and about ½ inch in length. It is very square in general appearance, as the edges of the elytra are almost parallel. The beetles are strong fliers and nocturnal in habit. The eggs are deposited in the oatmeal and after about two weeks the larvæ hatch. These are well known to all who keep birds or vivaria, where the mealworms form an important article of diet for carnivorous birds, lizards, etc. The body is long in proportion to its girth and of a very characteristic waxy yellowish colour. There are two small spines on the last segment. After several moults, pupation takes place and eventually the beetle emerges. The cultures seem to flourish best at a temperature of 29° C.

Tribolium castaneum Hbst.—The Red Grain Beetle.

This might be more correctly called a flour beetle, as it is unable to make the initial attack on the grains. It is found wherever grain is stored, but in conjunction with some beetle that has exposed the soft endosperm or amongst grains that have been damaged in some way or in flour or biscuits. Besides damaging the grain, this insect imparts a most unpleasant smell and taste to the food-stuff. The eggs are laid in the floury waste and give rise to elongated white glassy-looking larvæ. As these grow, this translucent appearance is lost and they become opaque and reddish yellow in colour. The length of the life-history is said to be about twenty-six days under normal conditions.

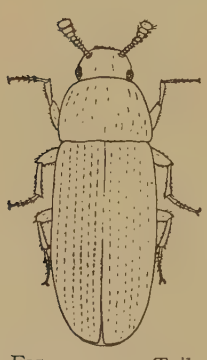

Fig. 123. — *Tribolium confusum*, imago. × 14.

Tribolium confusum is also found in flour. It is closely allied to the species just mentioned.

Gnathocerus (Echocerus) cornutus Fabr.

The broad-horned flour beetle is so named because the male bears large curved mandibles. This ferocious appearance is, however, not supported by any exhibition of prowess in battle. As a pest in flour and other crushed grains, *G. cornutus* can be of considerable economic importance. Curiously it flourishes best where there is the opportunity of a mixed diet of farinaceous and animal matter for its larvæ. Morison has demonstrated that this is the reason why it is generally found associated with *Ephestia kühniella* Zel., the Mediterranean flour beetle.

FIG. 124.—Larva of *Tribolium confusum*. × 14.

FIG. 125.—Pupa of *Tribolium confusum*. × 18.

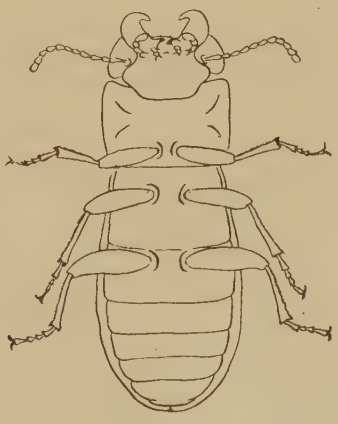

FIG. 126.—*Gnathocerus cornutus*, male. The broad-horned flour beetle. × 14.

The beetles, about 3·4–5 mm. in length, breed best at 70° F. and the eggs are laid singly amongst the flour. The larvæ hatch in about seven days and are characteristic of

the Tenebrionidæ. After a period of about six months, and after six moults, pupation takes place, and this often in the convenient cavity of the cocoon of *E. kühniella*. Morison describes the pupal stage as lasting 14–30 days and the length of life of the imago as about one year.

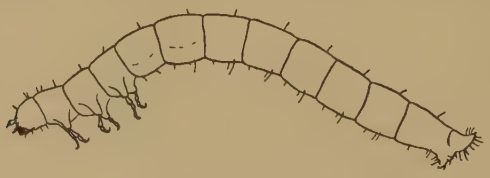

FIG. 127.—Larva of *Gnathocerus cornutus*. × 6.

His experiments show that "*Gnathocerus cornutus* can eliminate themselves from a culture when they are crowded together" by feeding on the eggs, larvæ, and pupæ of its own kind. So in a way, though it is a pest, it helps to act as a control from another pest. "It is not so harmful as the moth and can be exterminated more easily."

CHAPTER XI

INSECTA

Order DIPTERA

1. One pair of membranous wings born by the mesothorax. The mesothorax is much enlarged and in some cases there is a fusion of the thoracic segments. In place of the metathoracic wings of other insects are halteres ; these are in the form of small knobbed processes.

2. The mouth-parts are very variable, sometimes modified for piercing and sucking, sometimes only for sucking.

3. Metamorphosis is complete ; the larva is often maggot-like, but it is always without true legs.

This is one of the largest Orders in the animal kingdom, including something like 50,000 species. To this Order belong the insects commonly known as "flies." They are found in all parts of the world and a great number of them bring much harm to man and many other organisms. Indeed, if it were possible to eliminate certain species of Diptera, man would be free from some of the most deadly diseases. Many Diptera, on the other hand, lead blameless lives, and, as their staple diet is nectar, they are even useful in bringing about cross-fertilisation as they flit from flower to flower.

The classification of a large Order like the Diptera is a complicated affair and outside the scope of this book. Mention is made of only four of the ninety-eight Families, and readers are referred to text-books of Entomology for details of classification should they wish to pursue the subject.

Family Culicidæ

In Chapter I reference is made to certain members of this family, namely the genus Anopheles, in which the life-

cycle of the malarial parasite is completed and a brief outline of their life-history is given.

Family Piophilidæ

Piophila casei L. The Cheese Skipper.

A well-known member of this Family is *Piophila casei* L., a small black fly, with a particularly glistening surface, which lays its eggs on cheese of the better and richer kinds, and on various meats, especially in the fat of ham, bacon, and dried and smoked meats. Eggs are deposited on fresh meat, but decaying meat seems to be preferred. The eggs are white, elongated, and measure about 1 mm. in length. In suitable circumstances the larvæ hatch in about thirty-six hours; these are maggot-like, without legs, and they taper towards the anterior end. Legless though they are, they have a very remarkable mode of progression, for, drawing their body up till the head and tail are close together, they then straighten themselves with a jerk which causes them to jump some 2–5 inches. At a temperature of 80° F. the larval period is said to last about five days, and after voracious feeding during that time they measure about 7–10 mm. Pupation takes place in some dry spot, and the puparium, of a rich golden-brown colour, measures about 4–5 mm. in length. Under favourable conditions the life-cycle may take only twelve days, with an average of two generations a month during the summer. Beyond contaminating the food this organism does not seem to

Fig. 128.—*Piophila casei*. The cheese skipper. × about 35. (After Ealand.)

Fig. 129.—The larva of *Piophila casei*, the cheese skipper. × about 8. (After Howard.)

bring much harm to man, though cases of intestinal myiasis have been recorded as caused by the larvæ.

Prevention of this pest is accomplished by the use of screens in the larder, and on account of the small size of the adult the mesh should not be larger than thirty to the inch. Fumigation is a sure method of destruction—1 lb. sodium cyanide to 1,000 cubic feet should be used, but only by an expert.

Family Muscidæ

This Family provides the most commonly known genus of the Diptera—*Musca*.

Musca domestica L. The House-fly.

This is the common house-fly, a pest of man wherever he may be, either at the Equator or near the Poles, for it is recorded that house-flies appeared in the warmth of the hut used as the head-quarters of the Scott Expedition. So far as is known, they seem to serve no useful purpose; the old idea that they act as useful scavengers has long ago been replaced by the certain knowledge of the incredibly long list of troubles they bring to man. Their methods of feeding, their breeding habits, and indeed all their habits seem to aid their powers to do harm to man. And yet the house-fly is merely a conveyer and not an incubator of germs. It is more than curious to note that it was only so recently as 1910 that complete accounts of this organism and its life-history were published.

Fig. 130.—*Musca domestica*, female. The common house-fly. × about 4. (After Hewitt.)

All are familiar with the general appearance of the house-fly, an organism with a wing-span of about 13 mm. and body-length of 6 mm. The head is fairly large and the greater part of the surface area is devoted to the

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compound eyes—each consisting of about 4000 facets so arranged that some face upwards, downwards, in front, and to the side, enabling the fly to see in all directions without moving its head. A sexual difference is to be noted in the space between the eyes on the top of the head—in the female this is $\frac{1}{3}$ inch and in the male $\frac{1}{5}$ inch. The antennæ are three-jointed and bear a plumed arista. On the ventral side of the head is the proboscis, extended when in use, but withdrawn under the head at will. This proboscis is characteristic of the Muscidæ, and by a great modification of the usual insectan mouth-parts it provides an organ for the sucking up of liquid food. For the fly is incapable of either biting or piercing. The rostrum is the upper part of the proboscis — cone-shaped, attached to the head at its broadest end and bearing the sensitive maxillary palps with many sensory setæ. Below the rostrum is the haustellum, supported by chitinous sclerites and terminating in fan-like oral lobes. When taking food, the fly places the oral lobes on the lump of sugar; saliva is then passed down the salivary duct which runs through the proboscis. The saliva dissolves the sugar, and by the sucking action of the pharynx the sugar solution is sucked up the canals of the oral lobes into the pharynx and so into the capillary œsophagus.

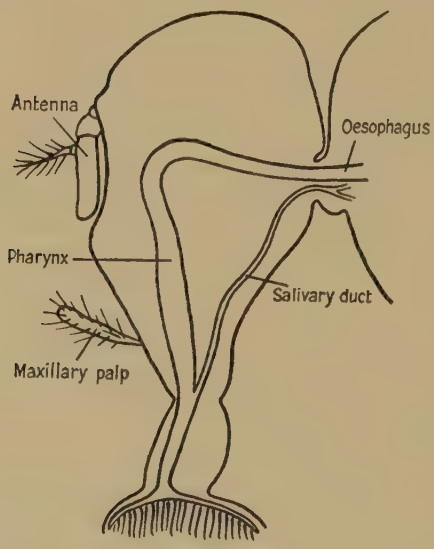

FIG. 131.—Diagram of the head and proboscis of the house-fly. (After Hewitt.)

The thorax consists mainly of mesothorax, which is greatly enlarged to support the one pair of wings. The

halteres are small, but are of importance, as they are supposed to have an auditory function. The legs are sub-equal in size, and the last joint of the tarsus bears the "foot." This possesses a large pair of claws and a pair of pulvilli or pads bearing many hairs, secreting a sticky mucous enabling the fly to walk upside-down on even a polished surface. All joints of the legs possess many setæ —an important point when the habits of the fly are under discussion. Of the wings little need be said—there is just the one pair and these are membranous. The abdomen is ovoid—only the 2nd, 3rd, 4th, and 5th segments are visible; the others are reduced or telescoped within the body. The powerful flight of the fly is accomplished not only by a strengthening of the mesothorax and the musculature in that region, but also by a general lightening of the body, brought about by the presence of large air-spaces or tracheal sacs which occupy a great proportion of the space within the contours of the head, thorax, and abdomen.

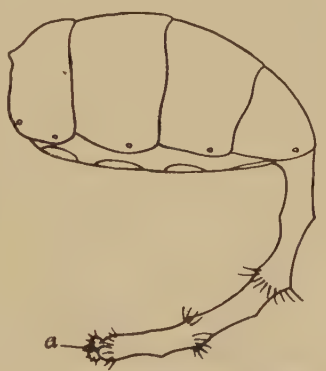

FIG. 132.—Abdomen of female house-fly with extended ovipositor. *a*. Position of anus. (Much magnified.) (After Hewitt.)

Flies are very dependent upon two factors in their environment, the abundance of food and the possibility of finding suitable breeding-places. These factors are of great importance in the extermination of flies, and it is just through their feeding and their breeding habits that they bring harm to man. Mention has been made of the use of the proboscis when feeding—a further consideration of the feeding habits is necessary. The food, rendered soluble by the saliva, is sucked up into the crop. Unfortunately flies are found in all places, clean and unclean; they feed on all sorts of matter; and as their favourite breeding-place is on dung-heaps, it is easy to realise that when they settle on human food the setæ on their body,

legs, proboscis, and the very saliva itself may be contaminated with bacteria they picked up on their last halt. It is probable that the saliva has a digestive action, for it seems necessary that a due amount should be mixed with the food. A fly will often settle, regurgitate the food in solution from the crop where the meal is temporarily stored, more saliva is poured on to it, and then the droplet or part of it is sucked up and passed into the proventriculus and so into the ventriculus and intestine.

FIG. 133.—Egg of house-fly, dorsal view. × 40. (After Hewitt.)

The favourite breeding-place is horse dung, but any fermenting heap of rubbish becomes a breeding-place. The eggs are laid just under the surface away from the light. Experimenters say that the female lays about 120 eggs at a time and she is capable of laying four batches in her life-time. However, it is recorded that one fly laid 2387 eggs in 21 batches in 31 days. As in the case of the blow-fly, the female has a wonderful way of gauging the amount of the food-supply for her young, and so she will lay the eggs in large or small groups accordingly. The eggs measure about 1·5 by ·3 mm., and at 25° C. they hatch in 8–12 hours; if the temperature is lower the incubation period is much longer. The larvæ when hatched measure about 2 mm. in length and are legless, cream-coloured, and taper towards the anterior end. After about 24–36 hours of eager feeding, ecdysis takes place, and again this occurs after a further twenty-four hours of rapid feeding and consequent growth. Another period of feeding precedes pupation, and the larva finds some dry spot, often going some distance to seek it, and, becoming quiescent, secretes the shining brown puparium,

FIG. 134.—Mature larva of house-fly. × about 5. *a.l.* Anal lobe, *a.s.p.* anterior spiracular process. (After Hewitt.)

accomplishing this in about six hours. After about five days the lid-like top of the puparium breaks and the adult fly emerges, very different in every way from the larva which gave rise to it. It is now known that during pupation many complicated changes have been going on and that the old tissues of the larva have been gradually broken down (histolysis) and the new tissues of the fly built up (histogenesis). The fly is sexually mature about fourteen days after emergence. Thus it is possible for a fly to be laying eggs 24–26 days after the egg from which it came was laid. In 1902 Berlese described how copulation takes place when the female is at rest, and not in the air, as might be supposed by the casual observer. The length of life is considered to be about two months. It has been shown that "sugar or some form of starch is an important factor in the longevity of adult house-flies and that it is necessary to oviposition." In the autumn the old flies all die off and the young and healthy, with large, well-filled, fat bodies, seek some warm and sheltered nook or cranny where they can hibernate. The emergence of flies in the spring seems to be controlled by the temperature.

FIG. 135.—Puparium of house-fly. × about 6.

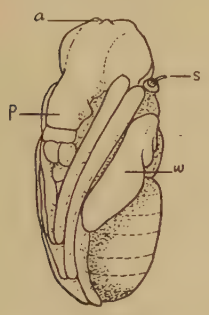

FIG. 136.—"Nymph" of house-fly dissected out of pupal case about 30 hours after pupation. *a*. Base of antenna, *p*. proboscis, *s*. spiracular process, *w*. wing. (After Hewitt.)

As already mentioned, the distribution of flies is, in a large measure, determined by the possibilities of food-supply and breeding-places, for unless helped by a carrying wind flies are not able to go far in search of either. Hewitt states that flies will travel as far as 1700 yards when in search of food or manure-heaps, but his experiments showed that usually they did not travel more than about 500 yards from their birth-place.

In temperate climates flies are, fortunately, only found during the summer months, but should the temperature be high and a plentiful supply of food be available for the larvæ, then breeding will be continued all the year round.

Enough has been said of the general structure and habits of the fly to indicate how eminently suitable it is for the part it plays in carrying disease. Its hairy, sticky legs are able to " pick up " bacteria and even larger organisms. Several experimenters have described how flies, caught at random, were made to walk over sterilised media in petrie dishes prepared for incubation. After incubation many different kinds of disease-causing germs were identified. Gaertner and Graham-Smith both point out that not only are bacteria carried on the external surface of the fly, but that micro-organisms may pass through the body and be dropped in a still active state in the fæcal matter or be regurgitated in the " vomit-spots " some time after the fly received the original infection.

The following is the list of diseases whose germs have been found on bacteriological plates : typhoid, cholera, enteric, diarrhœa, dysenteries, infantile diarrhœa, tuberculosis, plague, small-pox, diphtheria, leprosy, oriental sores, ophthalmia. It does not follow that because flies have been found with these germs that they must be accused of causing epidemics, but nevertheless much harm can be traced to the fly, and it is probable that the majority of the diseases in the foregoing list can be disseminated by flies. Besides, it must be noted that other things are transported by flies—such as the egg-cysts of Tænia and Nematode worms and the hypopal stages of mites. (See Chapter XIII.)

Control.—It is clear that flies are unpleasant things and their destruction should be aimed at. Many and various are the devices adopted. The covering of all food and so cutting off their food-supply is one of the most important things to remember. In this way the number of flies in a house can be reduced very considerably and the food kept free from contamination. Fly-whisks are of some use in combating the adults, but they demand

an undue expenditure of energy on the part of the user. Fly-traps account for thousands ; these are of many and various types : fly-papers, fly-ribbons, bread soaked in a dilute solution of formalin, etc. etc. Collet recommends spraying with hydrocarbide or with benzolene, care being taken to air the rooms thoroughly in case of fire. Attacks on the eggs, larvæ, and pupæ are most important, but it should first be noted that it is possible to so treat manure-heaps and collections of decaying and fermenting matter that the flies will be unable to oviposit. The heaps can be screened, treated with borax, or use can be made of the recipe of Berlese : 100 parts sugar-beet molasses, 5 parts sodium or potassium arsenite, 10 parts milk (even if skimmed or sour), the whole diluted with 5 or 10 parts by volume of water. Berlese recommends the strong solution for spraying the manure- and dust-heaps from May to October, when the early stages will be killed even if the flies should oviposit, and the dilute solution for the spraying of bunches of ivy or ferns, which should then be hung near the window and deter the flies from entering the house.

Calliphora erythrocephala (Mg.), the "blow-fly" or "blue-bottle," is a very well known insect with its loud characteristic buzzing when in flight. It is stoutly built and fairly large, its length varying from 7–13 mm. The wing-span is about 25 mm.

Fig. 137.—*Calliphora erythrocephala.* The blow-fly. × about 2.

The cheeks are reddish, hence the specific name. The thorax is bluish black with longitudinal markings and the abdomen a dark metallic blue. The halteres are rather small, the wings clear and typical of the Order. The legs are covered thickly with hairs and bristles. The species is widely distributed in Europe and North America, but observers notice that at temperatures below 55° F.

C. erythrocephala becomes sluggish and inactive, creeping away into some place for shelter till there is a rise in temperature, when activity will be renewed. It is probable that only the adults hibernate.

C. erythrocephala is really an out-of-door fly ; the males rarely, if ever, enter houses and the females only make their way in to search for a breeding-place. On emergence from the pupal case the male becomes mature in a few hours, but the females are not sexually mature for three or four weeks. This fact prevents the possibility of the fertilisation of the female by a male of the same brood.

The eggs are deposited on any fresh, decaying, or cooked meats ; they are also recorded as being laid in dead flies, fresh human fæces, plums, milk, sheeps' noses, and in open, unprotected wounds. The female appears to exhibit considerable discrimination while laying her eggs, taking into consideration the supply of food and then depositing as many eggs as she thinks fit. The female is fecundated only once, the eggs being fertilised at the time of deposition. The eggs are laid in batches, at intervals, about 180 eggs being mature at a time. The female is capable of producing in all about 450–600, though the records vary greatly, and Fabre considered from his observations that as many as 900 may be deposited by one individual.

The eggs are white and very similar to those of the house-fly. At a temperature of 23° C. they hatch in 10–24 hours, giving rise to a maggot about 2 mm. in length. This newly-hatched larva buries itself in the meat or carrion and begins to feed voraciously. During the larval life there are three ecdyses at intervals varying according to the temperature and the abundance of the food-supply ; the first 10–24 hours after hatching, the second twenty-four hours later, and the third after a further interval of about six days. The larva when fully fed measures about 18 mm. in length. It can be distinguished from that of *Musca domestica* by the structure of the posterior spiracle. When fully fed the larva ceases to feed and burrows into the earth or into a crevice of the meat, where it remains in a quiescent pre-pupal state for a period that varies

according to conditions from two days to several weeks or even months. This resting period is followed by the pupal stage, which may last for fourteen days. Thus a generation may be completed in 22–23 days.

Calliphora vomitoria L. is a closely allied species ; indeed the term " blow-fly " is applied to both these insects. The cheeks in *C. vomitoria* are black with golden-red hairs. The life-history and habits of the two species are very much alike.

Control.—The economic importance of *Calliphora erythrocephala* has been emphasised by many writers, for it has been proved that this insect is the mechanical carrier of the germs of typhoid fever, anthrax, swine fever, and of bacilli causing various intestinal troubles. Larvæ fed on food infected with anthrax have given rise to imagines capable of disseminating that disease. It is therefore clearly shown that *Calliphora erythrocephala* is a danger to man and cattle and that every care should be taken to destroy it or at least to reduce its numbers. This end is most readily accomplished by depriving the females of their breeding-places by the right care of all manure-heaps and the covering of all meats, whether cooked or fresh. Wardle has experimented with meat to ascertain the best method of protecting it. He found several powders, such as boracic acid, salt, chalk, and pepper, were efficacious so long as they remained undamped by the meat juice. Netting screens, $\frac{1}{4}$-inch mesh, perfumed with eucalyptus oil or formic acid, kept away the blow-flies for at least twelve hours, and aniseed oil for twenty-four hours. It is also recorded that a bunch of mint hung near meat is an excellent deterrent to the blow-fly. Experimenters have proved that the colour blue will act also as a deterrent.

Family Anthomyidæ

A close observer will notice the marked difference in size of the fly of the kitchen compared with that found in the bedrooms during the hot weather. This is explained

by the fact that *Musca domestica* is not the only fly commonly found in the house, though it seems to have a monopoly of the name " house-fly."

Fannia canicularis L. belonging to the above-named family is also a house-dweller. According to Austen, it appears earlier in the year, but seems to be outnumbered in the kitchens by *Musca domestica* in the later months. There are records from several districts: Howard, in statistics taken in the States, found 98 per cent. of *Musca domestica* and 1 per cent. of *F. canicularis*; Niven, in Manchester, found 3·4 per cent. of *F. canicularis*; Robertson, in Birmingham, found 4·7 per cent. of *F. canicularis*, etc.

FIG. 138.—*Fannia canicularis*, male. The lesser house-fly. × 4·5. (After Hewitt.)

The habits of this so-called " lesser house-fly " are very like those of *Musca domestica*. Records show that it is responsible for many cases of intestinal myiasis.

CHAPTER XII

INSECTA

Order HYMENOPTERA

1. Two pairs of membranous wings, with few or no transverse veins. During flight the smaller hind wings are secured to the fore wings by a series of hooks which pass over a fold on the posterior border of the latter, thus presenting a large and apparently unbroken wing-surface.

2. The mouth-parts are adapted for sucking and biting. The biting mandibles are often large and the maxillæ and labium form a tongue, used as a lapping organ.

3. Metamorphosis is complete.

The Hymenoptera is a large Order of about 60,000 species. The more well known members are the ants, bees, wasps, and ichneumon flies. Considered from the point of view of intellectual development, the Hymenoptera is the highest of the Orders of the Insecta. They exhibit a remarkable sagacity in all their doings. Many genera are characterised by their very elaborate communal habits, each one of the colony having its special role and particular duties. In these genera the phenomenon of polymorphism allows of great specialisation and adaptive characters. In the bee, for instance, there is the queen, whose main function in life is to produce eggs ; the drones, which produce the sperms ; and the workers, females with undeveloped genitalia, who do all the work of the colony, collect the honey, secrete the wax, make the cells, act as cleaners of the hive, caretakers of the royal nurseries, and attendants on the queen.

From the particular purview of this book the Order is not of very great importance and but little space can be allotted to it. The bees are mentioned owing to their habits of collecting honey and producing wax, and some

few of the parasitic forms are included because of the effect they have as a possible control of grain pests. These parasitic Hymenoptera constitute a very interesting study. They belong to widely differing Families, and it must be that these elaborately specialised life-histories are of independent origin. Fortunately in this climate the house-ant is an almost unknown pest and therefore a description of it is unnecessary.

Family Apidæ

Apis mellifica.

This, one of the best known of all the Insecta, not only belongs to this Family, but has given the Family its name. *Apis mellifica*, the honey bee, has been known and studied from very early times and the literature concerning it would fill a library. The reason why it should be included here is on account of two substances; the one, honey, which it collects laboriously in minute quantities from countless flowers, and the other the wax secreted from glands on the ventral side of the body. The honey is a plant product, and the long tongue-like labium is thrust down the flower to lap it up. The bee stores it in the hive for the purpose of feeding the young larvæ. For almost countless centuries man has robbed these storehouses. The bee is very rarely found wild, and the bee under "cultivation" will diligently fill and refill the man-made storehouses and will use whatever sugary food man may leave for the feeding of the larvæ. With regard

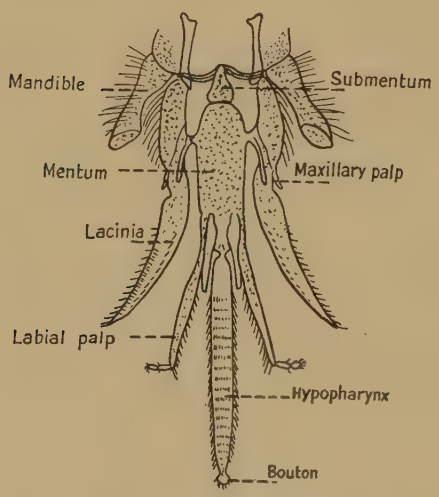

Fig. 139.—Diagram of the mouth-parts of the honey bee. (After Herms.)

to the wax, the part played by the bee is even more important. The wax produced by the bee is used in forming the cells for the storing of the honey. It is moulded into shape by the mandibles and pressed together to form the hexagonal chambers. The formation of large quantities of wax for this purpose reduces the amount of honey that the workers would otherwise collect, therefore it is not advantageous to expect the two products from the same set of bees. The bees collecting the honey are relieved of as much wax production as possible and the beeswax is mostly obtained from the wild bees of other varieties and genera. Further details with regard to the bees, their structure and life-history, should be obtained by reference to text-books of Entomology. In Part II there will be mention of both honey and beeswax.

FIG. 140.—Ventral view of abdomen of a worker honey bee. (The four pairs of wax scales shown in black. (After Folsom after Cheshire.)

PARASITIC HYMENOPTERA IN GRAIN AND FLOUR

In June 1916 the Grain Pests Committee was appointed by the Royal Society with the following reference: "To consider the relative economic importance of the species and varieties of insects infesting grain, to suggest measures for combating them, and to enquire into the extent of the actual loss from these pests." Part IX of the Report of this Committee is devoted to the consideration of the Hymenoptera parasitic on beetles found in grain and flour. The subject is discussed at length by Professor Goodrich, and the concluding paragraph in his "Note" puts us at once in possession of the main facts.

"In conclusion it may be stated that several species of Hymenoptera attack and eventually kill the larva of *Calandra oryzæ*, *C. granaria*, and *Rhizopertha dominica*, that these parasites considerably reduce the number of beetles infesting grain, but do not succeed in exterminating them because they themselves fall a prey to carnivorous acarids. Although the Hymenoptera may

well be considered as valuable allies in the fight against weevils, yet the results of this research do not justify the hope that they could be successfully used in practice to get rid of the grain pests."

To describe shortly the findings of Goodrich and Waterston with regard to these organisms, the story is as follows : Genera belonging to five Families were found in various samples of stored grain and flour, in all at least twenty-four species, the majority belonging to the Families Chalcidoidea and Vespoidea. It is therefore impossible to speak more than generally concerning them. The imagines are minute, often with delicate little dark-coloured bodies and a pair of fine membranous wings. The antennæ are often club-shaped and provided with delicate setæ. The following extract from one of Waterston's descriptions gives some idea of the wonderful diversity of colouring in so small a creature :

FIG. 141.—*Lariophagus utibilis.* × 25. (Camera lucida drawing from a culture in wheat.)

" *Bruchobius laticeps.* —Head, thorax and coxæ, dark green, at most with submetallic aeneous or dark-blue reflections. Eyes, dark chocolate, pubescence paler. Abdomen, smooth, shining, immaculate, metallic with aeneous or purplish reflections. Antennæ, scape, clear yellowish brown (light honey-colour). . . .

" Legs : tarsi, pale whitish ; fore tibiæ, brown, narrowly paler at base ; mid and hind tibiæ distinctly paler at base, then brown to about two-thirds and broadly pale apically ; femera brown. . . .

" Wings, hyaline. Veins, blackish-brown."

They may be present in large numbers and in a labora-

tory culture they fly in little swarms above the grains. The deposition of the eggs has never been seen, but it is likely that the egg is laid in the cavity of the grain occupied by the beetle larva. The beetles mentioned above have soft-bodied succulent larvæ, and it is therefore understandable that they are more liable to attack than, say, the larvæ of *Tribolium confusum* or *Gnathocerus cornutus*. The parasite hatches after only a short incubation period and proceeds to devour the beetle larva. " Every beetle larva attacked is irrevocably condemned to death."

The Chalcid develops rapidly, the larval and pupal stages both being short, and the dainty little adult emerges. Quoting Goodrich again : " It might, therefore, be thought that they would soon exterminate the beetles ; but this never seems to happen, at least in laboratory cultures." For the Chalcid falls before the ravages of a mite *Pediculoides ventricosus* Newport, a most remarkable organism. " In a grain of wheat are often found the shrivelled remains of the *Calandra* larva on which the Hymenoptera larva has fed, the dead or dying Chalcid imago, and the *Pediculoides* attached to it. Thus the whole series of events is permanently recorded in chitin and the complete tragedy can be unfolded."

CHAPTER XIII

Class ARACHNIDA

The Arachnida is numerically a much smaller Class than that of the Insecta, and yet it shows greater diversity in nearly every respect, including as it does such forms as ticks, mites, spiders, king-crabs, and scorpions. The more primitive members are aquatic and breathe by laminated gills (king-crab). The primitive air-breathing types are possessed of laminated respiratory organs also, but, comparatively, much smaller and enclosed in small chambers on the ventral side of the body. These lung-books, as they are called, are found in spiders and scorpions. In higher types the lung-books are absent and a tracheal tube system is developed ; though in some spiders both lung-books and tracheal system are functional. In some mites there is no respiratory system, as even the tracheal tubes are absent. The body-form is quite characteristic : usually it is divided into the cephalothorax and abdomen, but in the mites this distinction is lost and the body is down-like in appearance. There are twenty segments though, as in the Insecta, these are generally indistinguishable. There are two pairs of mouth-parts, the claw-like cheliceræ with poison gland at their bases and the six-jointed sometimes leg-like pedipalps. There are four pairs of legs in the adult. The heart is tubular, supplied with paired ostia and extending right through the abdomen. The alimentary canal is straight, passing from an anterior mouth to a posterior anus. The nervous system has a dorsally placed supra-œsophageal mass ; variation is to be noted in the nerve-chain and in the concentration of the ganglia in the thorax and abdomen. There is also considerable variation in the different Orders in the position and number of the eyes. The Arachnida are diœcious and generally oviparous.

Order ARANEIDA—The True Spiders

The great chitinous shield covering the cephalothorax is furrowed at the posterior margin of the head. The eyes are on the dorsal surface of the head and are usually eight or six in number. The abdomen is soft, segmentation is indicated in only a few cases. There are two or four pairs of spinnerets on the ventral side of the abdomen. With these the webs, so characteristic of the Araneida, are spun. The type of web varies a great deal, from the loose, uneven, untidy snare of the house-spider to the carefully constructed webs of the garden-spiders. The webs are, of course, for the purpose of catching and holding the prey, and as spiders can only take liquid nourishment from live prey, the web is a necessity.

The Order Araneida is a comparatively large one, and it is widely distributed and includes terrestrial and aquatic forms.

Tegenaria domestica and **T. derhamii** are two of the more common house-spiders. So far as is known they do not bring any harm to man, but are found in the house in undisturbed corners. Their loosely made snares are conspicuous, especially when the dust and flies accumulate in them. A nest is made at the back of the snare, most usually in the angle of the wall. This is reached by a small opening, and in it the spider awaits her prey and her husband. The small insignificant male approaches her with some caution ; if his offers are not considered favourably, he is usually killed and his body fluids sucked at once. A similar end is, however, awaiting him even if he is at first received as a mate. For after the transference of the seminal fluid the female solves all matrimonial difficulties by devouring him. The eggs are laid in a cluster, and after a time the minute young spiders hatch out. Their homicidal parent has either moved on to another corner or is dead, so in any case the young have no maternal care.

A thorough and frequent cleaning and brushing in likely corners is the best way of keeping free from house-spiders.

Order ACARINA—The Mites

The organisms included in this Order are often described as "degenerate Arachnids." They are as a rule minute. There are a great many species, but what is most characteristic is the vast number of individuals that are developed, for under favourable circumstances the rate of reproduction is rapid. Most mites live on liquid nourishment, and as the meal proceeds the body becomes distended. In nearly all other respects they are of very varying habits and are found on both animals and plants, whether these be alive or decaying. There is great variation in shape,

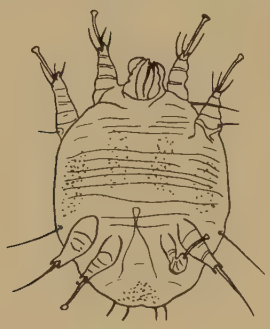

Fig. 142.

Fig. 143.

FIG. 142.—*Sarcoptes scabiei*, male. Ventral view. The itch mite. × 150.
FIG. 143.—*Sarcoptes scabiei*, female. Ventral view. × 190.
(After Bourguignon.)

but the majority are more or less oval, flattened dorso-ventrally, or more usually dome-shaped. The chelicerae are claw-like or like stylets and used for piercing. The pedipalps are usually leg-like. The pharynx has a powerful sucking action. It is considered that many mites are without a respiratory system. The air is taken in through the body-wall, and this accounts for a certain humidity of atmosphere being necessary for these organisms. If desiccation should take place the mites die off at once.

Family SARCOPTIDÆ

Generally without eyes. Body rounded posteriorly, skin wrinkled. No genital suckers.

Sarcoptes scabiei var. **hominis** L., 1758. The Itch Mite.

This particular mite causes scabies in man, a most unpleasant skin complaint. An intense irritation is an important symptom, and hence the colloquial name "itch mite." The females measure 330–450 μ by 250–350 μ, while the males are much smaller: 200–235 μ by 145–190 μ. The sexes meet on the surface of the skin of man, and the males, being short-lived, quickly die. The female proceeds to burrow under the skin, especially where it is soft, e.g. the interdigital spaces of both hand and foot, the wrists and the softer skin of the arms, the pelvic area and buttocks, the ankles and the back of the knees. The burrows vary in length and may be as long as half an inch. It has been stated that her digging powers are such that "she can bury herself in 2½ minutes." Burrowing is generally carried on at night, and this explains the extreme irritation felt during that period. Not only does the burrowing cause a disturbance, but small vesicles are formed in their vicinity. The female never returns from her tunnel, but goes farther and farther, laying her eggs and depositing excrement, so blocking the exit. The tunnel, taking a sinuous course just under the skin, may be seen with a lens, demarked by the dark fæcal matter. The female is probably able to lay about 40–50 eggs, and she eventually dies in the grave she has made for herself. The eggs are very large compared with the parent; they measure 150 μ by 100 μ. After about 2½–4 days the egg laid first, that nearest the opening, hatches and the six-legged larva is formed. This changes

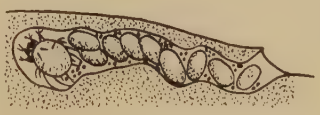

FIG. 144.—Diagrammatic view of the tunnel made by the female itch mite under the skin of the host. (After Guiart and Grimbert.)

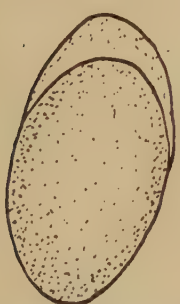

FIG. 145.—Egg of itch mite. × 180. (After Bourguignon.)

into the eight-legged nymph, and finally into the adult, complete with genitalia. Each successive egg gives up its young and in a short time the mite population is considerable. In vain attempts to allay the irritation the patient often aggravates the evil by rubbing into the broken skin bacteria, the dead mite and other harmful things. The disease is treated by the application of sulphur ointments and thorough scrubbing and washing with soap and hot water. Ehlers' ointment is said to effect a cure after only one application. The following is the recipe :

" 1 kilogramme of sublimated sulphur is dissolved at a gentle heat in 2 kgs. of a 50 per cent. solution of potassium hydroxide. This makes a clear, yellow solution. 225 grs. of vaseline and 225 grs. of water-free lanoline are carefully mixed without heat. To this mixture add 375 grs. of the sulphur solution mentioned above. Make fresh zinc hydroxide by mixing 28 grs. of zinc sulphate and 40 grs. of 20 per cent. sodium hydroxide, and add this to the ointment. Liquid paraffin is added to obtain a total weight of 1,000 grs., and 5 grs. of benzaldehyde is added to check the smell of sulphuretted hydrogen."

The clothes and bedding of the patient should be carefully treated by disinfectant washing or by baking.

There are many species of Sarcoptes attacking various animals, cats, horses, etc. Experiments show there is the possibility of the transference of these forms to man with harmful effect, though not so serious as that caused by the parasite peculiar to the human.

Family Tyroglyphidæ

No eyes. Skin smooth and without parallel wrinkles of the Sarcoptidæ. Said to be without tracheæ.

Tyroglyphus

The genus *Tyroglyphus* supplies several species and varieties of mites which are found normally in certain food-stuffs : *Tyroglyphus siro*, the cheese mite ; *T. longior* in cheese, flour, bran, and a variety of situations ; *T. longior* var. *castellanii* in copra. But though found in the

food-stuffs, these mites may cause " itch " in those who have the handling of them. Conjunctivitis has been traced to this cause. An interesting point in the life-history of this genus is that there is a developmental phase, preceding the final moult, which results in the formation of the imago. This is termed the hypopus. On the ventral side of the abdomen is a small sucker or hypopal plate—a special organ appearing at this stage only and disappearing with the last ecdysis. The function of this organ is to enable the hypopus to adhere to the legs of a fly or beetle and thus to effect transportation to another spot.

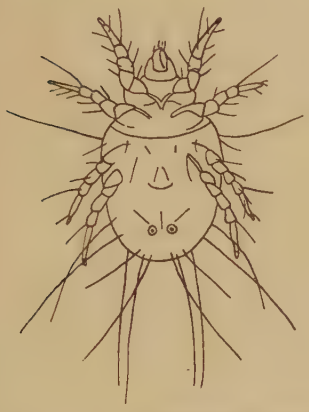

FIG. 146.—*Tyroglyphus longior*, male. Cheese mite. × 78. (After Newstead and Morris.)

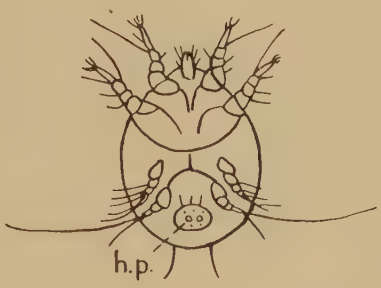

FIG. 147.—Hypopus of *Tyroglyphus longior*. × 117. *h.p.* Hypopal plate (After Newstead and Morris.)

Tenebrio molitor has been found conveying these creatures on the hairs of its body, legs, and antennæ. This means of distribution greatly adds to the difficulties of combating mites.

Glycyphagus domesticus (de Geer) is also a Tyroglyphid. It is found in sugar, and it, or closely allied species and varieties, are found in straw, hay, matting, etc. Attacking man, it causes what is called " grocers' itch." It often gets into furniture and various " stuffings," and though it does not seriously damage a house and its furniture it is most difficult to extirpate and is a most annoying and messy inhabitant.

All these mites are unable to withstand desiccation, so that the humidity of the atmosphere of the store-room or cupboard is a most important factor. As with the "flour mite," mentioned later, the moisture-content is at a safe limit if it is kept below 11 per cent. If it rises to 12 and 13 per cent. mites will flourish. Dr. Eales, in her paper dealing with the cheese mites, emphasises the importance of screening cheese-rooms to keep the flies out. She also mentions the care with which the cheeses should be brushed with a dry brush or, better still, with one moistened in carbon bisulphide. Three such applications at intervals of three days should free the cheeses of mites. The shelves (preferably of glass, stone, or slate), floors, walls, and ceilings of the cheese-rooms should be washed with disinfectants, 5 per cent. carbolic acid, at regular intervals or frequently lime-washed. Fumigation is very efficacious in destroying mites—carbon bisulphide, 1 lb. to every 500 cubic feet. A second fumigation is necessary 12 to 14 days later. It should be noted that it is impossible to use some fumigants in the presence of the food-stuff itself, for it has been proved by Simmons that hydrocyanic acid gas is retained by fumigated cheese, which is rendered poisonous. There are also fumigants which affect adversely the process of ripening even if they leave no smell or taste.

Aleurobius farinæ (de Geer)—The Flour Mite

This is a frequent and serious pest in grain, bran, rolled-oats, oatmeal, flour, and cheese. It is responsible for the greater part of the damage done by Acarids. It attacks sound wheat-grains by boring a hole in the epicarp just in the embryonic region. The mites enter the grains in great numbers, eating first the embryo and then the endosperm until nothing is left but husk. The life-cycle has been worked out by Newstead and the following account is a summary of the results he obtained in June and July at a temperature varying from 64–71° F. in a moist atmosphere. The female produces in all from 20–30 eggs, depositing them on the food and scattering

them about, laying three or four eggs in a day. These are oval, white, and smooth, and measure ·12 mm. by ·08 mm. After about three or four days the hexapodous larva is hatched ; it begins to feed at once and grows rapidly, till at the end of the third day it moults and gives rise to the nymphal stage. The nymph has four pairs of legs. It moults six or eight days later, giving rise to the adult. The adults copulate a day or two after ecdysis and the females lay eggs two or three days after this. *Aleurobius farinæ* is peculiar amongst the Acarids in having only one nymphal stage. Thus at a temperature of 64–71° F. the

FIG. 148.—*Aleurobius farinæ*, male. Flour mite. × 78. (After Newstead and Morris.)

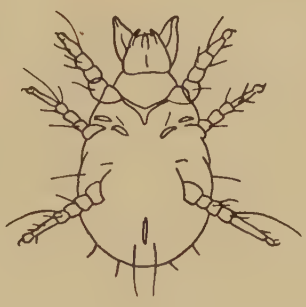

FIG. 149.—Larva of *Aleurobius farinæ*. × 220. (After Newstead and Duvall.)

complete cycle from egg to egg is accomplished in seventeen days, but at lower temperatures this time is extended. In laboratory cultures mites sometimes multiply in an astonishing way, and the culture jars and incubators become covered with millions of these pests. It is now an undoubted fact that mites may be found in the storehouses at all times of the year, though they are most plentiful and consequently do most damage in the summer and autumn. Their presence may be detected by a peculiar and unpleasant smell known as "musty" or "mitey." When they are present in the flour there is a characteristic appearance on the surface, where their tracks or burrows may be seen.

Control.—The experiments carried out by Newstead show that the moisture-content of the store-house or store-bin is an important factor in the life of the mite ; for the mites, breathing as they do, through the skin, require a certain moisture-content of 11 per cent. Less than this percentage is unfavourable to the mites and the stores will be uninjured ; but if the moisture is over 13 per cent., the mites will increase rapidly, and by their presence in vast numbers the moisture-content will be appreciably raised and the stores rendered liable to further damage from moulds and fungi. Desiccation not only destroys the adults and nymphal stages, but will, if prolonged, destroy the life in the egg.

Family Tarsonemidæ

Minute, soft bodies, sometimes show indications of segmentation. No suckers. Sexual dimorphism marked.

Pediculoides ventricosus Newport

This mite has already been mentioned (p. 145, Chapter XII) in connection with its habits of parasitising the Hymenopterus parasites attacking *Calandra oryzæ*, *C. granaria*, and *Rhizopertha dominica*, in stored grain. It is responsible for " itch " among workers dealing with corn, cotton-seed, barley, and straw. It is found on the stalks of the growing corn, feeding on the vegetable juices. It has been proved that this mite is capable of causing a serious infection in a few hours only, with skin eruptions of a great severity. The disease is known as " grain itch." There are no larval stages, as the adult is produced directly from the eggs.

Family Trombidiidæ

Soft bodies. Eyes present. Cheliceræ modified for biting.

" **Leptus** " (**Trombicula** ?) **autumnalis** (Shaw)

The velvet or harvest mites are the adults of larvæ which are a very annoying and indeed painful parasite

of man. The adult harvest mites themselves live on the juice of various plants, such as reeds, daisies, fruit trees, and heather, and the young, hatching out from the eggs deposited thereon, attack the arms and legs of those human beings who come near them. They penetrate the skin and cause quite a painful wound which raises a swelling. They can become a serious pest to workers in the fields, wood-cutters, etc. All are not affected alike, as the blood of some persons seems to be more to their taste than that of others.

FIG. 150.—"*Leptus*" (*Trombicula?*) *autumnalis*. The harvest bug. (Much enlarged.) (After Hirst.)

There are probably several genera of harvest mites who have this liking for human blood, but the life-history is somewhat difficult to work out. It is only comparatively recently that the harvest bug *Leptus autumnalis* has been proved to be the larval stage of the harvest mite.

Preventions are often used in vain, but oil of citronelle and flowers of sulphur rubbed on or dusted over the arms and legs will sometimes be useful.

CHAPTER XIV

THE GENERAL CARE OF THE PERSON AND THE HOUSE

In the preceding chapters the animals harmful to man and his household are described and remedies are recommended for each particular evil as it is recounted. Some advantage may be gained, however, by emphasising and collecting certain items of this advice, and therefore no apologies are offered to the reader for adding what might seem to be an unnecessary chapter, and thereby recapitulating some of the statements made in the earlier part of the book.

Unfortunately in almost every country there are organisms ready to prey upon man and his possessions ; this is not always so obvious in the colder climates, but everybody must be aware that it is very true of the temperate, semi-tropical, and tropical countries. A great part of the time and energies of the health officer, social worker, institutional manager, housewife, and the doctor is spent in the struggle to minimise the evils they bring or if possible to do away with them altogether.

The Personal Pests of Man

Under this heading are included the bug, flea, louse, and itch mite. Speaking generally, with regard to these organisms the ordinary person is able to be free from trouble by the adoption of cleanly habits, i.e. a reasonable amount of bathing and cleansing of the person, clothes, and bedding. By this constant care a chance visitant is quickly located and destroyed before it has the opportunity of establishing itself in its new quarters. Those whose work may bring them into contact with persons

likely to harbour these creatures may adopt certain protective measures for their persons, i.e. smooth-faced clothing and a covering for the head and hair. With regard to the louse and itch mite it must be emphasised that these are personal pests, living on the human and breeding thereon ; but that the flea and the bug breed away from the human, in the bedding in the case of the flea and in the bedding or crannies in the bedstead, of walls and floor of the rooms of the " buggy " house. Reference should be made to Chapters VI and VII for the treatment of clothing, bedding, and furniture, and of the person.

General Care of the House and the Use of Insect Powders

Those having the care of a house or institution generally see that there is an annual cleaning, when all possessions are looked over, repaired, and cleaned in the method appropriate to their kind. This most excellent but disturbing proceeding is commonly termed " spring-cleaning," and takes place when the lengthening and brightening days reveal the need for the more searching and thorough process of " cleaning down " in contra-distinction to the weekly " cleaning up." Housewives would do well to remember that to be really efficient this " cleaning down " should be a biennial function, for several household pests would thereby be dislodged before the hibernation for the winter. Unless the housewife begins in the very early spring, the hibernation period is over and the insects are ovipositing before she is ready with her plans for the great campaign.

In the hands of a thoughtless housewife insect powders are often almost useless. In most cases these powders retain their efficacy for a short time only, or are at least less potent after prolonged exposure to air. To get the maximum benefit, therefore, the powder should be sprinkled at dusk when it is to destroy such nocturnal organisms as cockroaches, silver-fish, bugs, etc. (See Chapters VI, VII, IX, X, XI.)

The Care of Store-room and Larder

In the first place the store-room and larder should be cool and dry, and these conditions are most easily procured by placing these very important rooms on the north side of the building. In many cases a low temperature is obtained by using a basement, but in doing so it must be remembered that basements are frequently damp, and while coolness is certainly a character of basements, the temperature is not low enough to prevent the breeding of organisms which may attack stored food. The walls, floor, and shelves should be as smooth as possible, in order that there shall be few irregularities, for in the case of many pests the adults deposit their eggs in such places. The ideal condition is tiling for the walls and floor, and stone or slate for the shelves—these can be readily washed, and the washing rendered more useful by the addition of a little carbolic acid or formalin to the soapsuds. If tiling is impossible, the brick or plaster or cement surfaces should be washed over with specially prepared solutions, the whitewash for the walls having the addition of a little formalin and the floors washed with soapsuds and carbolic acid or formalin. This cleansing of the walls, floor, and shelves should not be merely an annual affair, the walls should be re-washed at least twice a year, in the spring and autumn, and the floor and shelves should be cleaned as often as possible or at least weekly. In both store-room and larder prevention is better than cure and special attention should be paid to the windows. A certain amount of air is of course necessary, but the incoming air must be prevented from bringing with it undesirable visitants. To accomplish this, the window must be screened. For this purpose wire gauze is often used, but the impecunious housewife whose landlord is ignorant of the requirements of a satisfactory larder may make a very effectual screen with a fine muslin of a mesh 30 to the inch. It goes without saying that the doors of both places should fit well and be kept closed whenever possible. It is obvious that the door must sometimes be open, and

therefore precautions must be taken to cover all food or storage bins. Meat-covers can be obtained, and these kept over fresh food of all kinds, not only meat. Again, the housewife may economise and with a little ingenuity provide herself with substitutes covered with muslin. In all cases the covers should be much larger than the food to be covered, for the house-fly and blow-fly will oviposit through the wire or muslin cover should the meat, etc., be touching it or even near enough to be reached by the ovipositor. Besides the pests which fly to the food, protection must be sought against those that crawl. The simple method of raising the dish of food upon a straight-sided tall jam-jar will save it from the attacks of cock-roaches, silver-fish, and even mice. In the larder, where the avoidance of moisture is not quite so imperative, an increased protection is gained by standing the supporting jam-jar in a soup-plate of water—the water being an impregnable barrier to mites. In the store-room, where there may be dry foods in quantity, great care should be taken with regard to certain points. Where possible cereals, in fact all foods, should be stored in tins or earthenware containers through which organisms cannot obtain entrance by gnawing or burrowing. In the case of cereals to be stored for any length of time, there should be a close correspondence between the amount to be housed and the space which is to contain it ; for where there is a small amount of wheat or flour in a large space the air readily acquires moisture and so provides conditions suitable for the breeding of mites, flour moths, and flour and grain beetles (see Chapters X, XI, XII, XIII).

The Care of Stored Fabrics

Fabrics, such as silk, wool, and fur, are most safely stored at temperatures low enough to prevent the pests from ovipositing. But this " cold storage," at not more than 5° C., is an expensive method. The majority of people cannot afford it and must adopt a less ambitious scheme. To prevent oviposition is the first aim, and therefore the use of various unpleasantly smelling sub-

stances is advocated. Many of these substances lose their virtue by evaporation and a regular examination of the articles is necessary ; they should be shaken out in the sunshine, exposed to the air, refolded, and the " moth preventer " replenished. The use of old newspapers, with the printer's ink abhorrent to clothes moths, should not be forgotten ; this is mentioned in Chapter IX.

The Care of Wood and Furniture

The best prevention that can be recommended is the frequent use of a good furniture polish, rich in paraffin oil or turpentine. This should be used lavishly, not only on the parts intended for display, but the wise housewife will apply her polish to the undersides of tables, the back of the chest of drawers, in fact on all the surfaces. If she is truly wise she will pay greater attention to these rather rougher places, for it is in the cracks and corners that the furniture beetles oviposit. Paraffin and turpentine seem to be distasteful to them, and so they will pass on and lay their eggs elsewhere. (See Chapter X.)

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GLOSSARY

ANOPLURA.—Means, literally, "unarmed"; "wingless insects having no tail appendage." The Lice.

ANTENNA.—The first pair of appendages in the Insecta, generally feeler-like and composed of many joints.

ARACHNIDA.—The Class to which the spiders belong.

ARTHROPODA.—The phylum of invertebrates, including organisms possessing jointed appendages.

ASEXUAL REPRODUCTION.—A method of producing progeny without the intervention of sexual cells, e.g. by budding, by simple division, etc.

BINARY FISSION.—The process whereby a cell divides into two daughter-cells.

BLADDER WORM.—A stage in the life-history of a tape-worm—generally known as the cysticercus.

CÆCAL GLAND.—A gland of the cæcum or blind diverticulum of the alimentary canal.

CARNIVOROUS.—The habit of preying upon some animal; flesh eating.

CERCARIA.—The larval form of a Trematode worm; generally has an elongated heart-shaped body propelled by a tail.

CEREBRO-SPINAL FLUID.—The fluid contained in the cavity of the spinal cord and brain.

CESTODA.—The tape-worms.

CHITIN.—A carbohydrate secreted by the epidermal cells of the Arthropoda. It hardens on exposure to the air, forming a covering or "tunic."

CHROMATIN.—The part of the nucleus which takes up certain stains with avidity.

COCOON.—The "shell" or covering enclosing the pupa of an insect. Often called a chrysalis.

CŒLENTERATA.—Diblastic animals possessing only one cavity in the body—the digestive cavity.

CŒLENTERON.—The body-cavity of the Cœlenterata.

CŒLOM.—The body-cavity which is lined by mesodermal epithelium and lies between the body-wall and the gut. Present in cœlomate Triblastica.

COLEOPTERA.—An order of Insects possessing heavily chitinised anterior wings which form a sheath or covering for the membranous flight wings borne by the metathorax.

"COLLARED" CELLS.—Flagellated cells found in the chambers of the canal system of sponges. The base of the flagellum is surrounded by a protoplasmic structure collar-like in form.

COMMENSALISM.—"That association in which hosts tolerate their parasites as guests or mess-mates" (Cleveland).

CONNECTIVE TISSUES.—Tissues derived from mesoderm and possessed of a number of fibres of different types.

CONTRACTILE VACUOLE.—A small vesicle present in many Protozoa. It becomes filled with excretion which is liberated at intervals, causing the vacuole to collapse.

COPULATION.—The act of sexual intercourse, when the sperms are passed from the male to the female.

CROP.—A part of the alimentary canal where the food is stored temporarily, as in the house-fly.

CUTICLE.—An outer covering secreted by the epidermis.

CYST.—A resistant protective covering formed round an organism during a period when adverse circumstances have to be faced or during a period of rest.

CYSTICERCUS.—The name applied to the bladder-like larval form of the tape-worm.

CYTOSTOME.—"The cell-mouth."

DIBLASTICA.—Animals whose body-wall possesses only two cell-layers, the ectoderm and endoderm (the Cœlenterata).

DIMORPHIC.—Name applied to organisms which exhibit two forms; e.g. sexual dimorphism, where the male and female differ in structure.

DIPTERA.—The Order of Insecta possessing only one pair of wings.

ECDYSIS.—The casting of the skin or covering.

ECTODERM.—One of the three "germinal layers." It gives rise to the outer layer of cells in the multicellular animals and the various structures derived therefrom.

ECTOPARASITE.—An organism that lives on the outside of another and takes its nourishment from it.

ELYTRA.—The heavily chitinised fore wings of the Coleoptera.

ENCYSTMENT.—The process resulting in the formation of a protective cyst.

ENDODERM.—The innermost of the three "germinal layers." It lines the greater part of the alimentary canal.

ENTEROZOA.—The group which includes all the animals possessing an alimentary or digestive tract, i.e. all animals except the Protozoa and the Porifera. Used by Ray Lankester.

EPIPHARYNX.—A projection from the dorsal wall of the pharynx in the Insecta. In some this may form quite an important mouth-part.

EUCERATOSA.—The group of Porifera possessing a horny skeleton.

EXCRETION.—The process whereby an organism gets rid of waste matter.

FLAGELLATA.—Protozoa possessing a whip-like protoplasmic organ of locomotion.

"FLAME" CELLS.—The hollow terminal cells in the excretory system of the Platyhelminthes. The flickering movements of the cilia in the cavity are characteristic.

FRENULUM.—A projection on the hind wing of Lepidoptera which enables the two wings of the same side to become temporarily attached.

GAMETE.—A sexual germ-cell.

GAMETOCYTES.—The cells which give rise to the gametes or sexual germ-cells.

GANGLION.—A group of nerve-cells forming an enlargement in a nerve-chain.

GENUS.—A collection of species closely related to one another and having certain characters in common.

GONOPODIUM.—Projections of the posterior abdominal segments which assist in the process of oviposition. The gonopods in the female louse hold the hair while the egg is being attached to it.

HABITAT.—The natural home of an organism.

HALTERES.—Small knobbed structures found in the Diptera on the metathorax in the place of posterior wings.

HERBIVOROUS.—Vegetable feeders.

HERMAPHRODITE.—Possessing male and female genital organs.

HEXACANTH.—The larva of the tape-worm, so-called because of the three pairs of hooks that it possesses.

HISTOGENESIS.—The formation of tissue.

HISTOLYSIS.—The breaking down of organic tissues.

HOST.—The name applied to an organism that harbours a parasite.

HYBRID.—The progeny resulting from the cross-breeding of two animals or plants of differing species.

HYPOPHARYNX.—A structure developed from the floor of the pharynx in some of the Insecta. This may play an important part in the taking of food.

IMAGO.—The adult form of an insect.

INDIGENOUS.—Native to a particular locality, belonging naturally to a certain place.

INGESTION.—The taking in of food-material.

INTEGUMENT.—A covering skin or layer.

LABIUM.—The lower lip of an insect, formed by the union of the two second maxillæ.

LACINIA.—The internal portion of the first maxilla of insects.

LARVA.—A phase in the life-history of many animals ; an active immature stage that is very different from the adult.

LEPIDOPTERA.—The order of Insects in which the wings are covered with scales.

LUNG-BOOK.—The respiratory organs in the Arachnida—small sacs with folds of respiratory tissue.

LYMPH.—A fluid of the body, colourless and alkaline.

μ.—The accepted sign for the unit of microscopic measurement, = ·001 mm. Also called a micron.

MACROGAMETE.—See Megagamete.

MALPIGHIAN GLAND.—Glands of the intestine found in Insects. They are excretory in function.

MANDIBLES.—As used here it is the name given to the second pair of appendages in the Insecta. Most generally they are heavily chitinised and used for tearing or biting the food. In the Vertebrata the word is applied to the one half of the lower jaw.

MASTIGOPHERA.—The Protozoa bearing whip-like structures.

MAXILLÆ.—The third pair of appendages in the Insecta, often highly modified, and functioning as mouth-parts.

MEGAGAMETE.—The female germ-cell, larger than that of the male.

MEROCYTE or SCHIZONT.—See SCHIZONT.

MEROZOITE.—The small cells formed by the fragmentation of the schizont or merocyte.

MESENTERON.—The middle portion of the alimentary canal, lined by endoderm cells.

MESODERM.—The middle of the three germinal layers.

METAMERIC SEGMENTATION.—The term applied to the type of body-structure found in many organisms, e.g. the tape-worm, where the body consists of a series of like parts or segments.

METAMORPHOSIS.—A process whereby an organism undergoes a more or less abrupt change as it passes from one phase of its development to the next.

METAZOA.—The multicellular animals.

MICROGAMETE.—The male generative cell, smaller than those of the female.

MULTIVOLTINE.—The term applied to races of silkworms producing more than one brood in a year.

NEMATHELMIA.—The phylum, including the thread-worms and forms closely related to them.

NEMATODA.—The thread-worms.

NUCLEUS.—A specialised part of the protoplasm of a cell, generally containing the chromatin.

NYMPH.—The stage in the metamorphosis of an insect preceding the imago. The term is applied to an active type corresponding to the quiescent pupa.

OCELLUS.—An eye-spot or marking on the head of an insect having the appearance of an eye.

ŒSOPHAGUS.—The part of the alimentary canal leading from the pharynx to the stomach.

ORTHOPTERA.—The Order of Insects with straight wings.

OVIPAROUS.—An organism is said to be oviparous when it produces its young in the form of an egg.

PÆDOGENESIS.—Applied to the condition when larvæ give rise to young before they themselves become adult.

PARASITE.—An organism living on or in another organism which is called the "host"; the parasite living at the expense of the host.

PARAZOA.—The word used by Sollas to include the Porifera and to distinguish them from the Enterozoa.

PARTHENOGENESIS.—The production of progeny by an unfertilised female.

PATHOGENIC.—Disease producing.

PHARYNX.—The part of the alimentary canal leading from the buccal cavity to the œsophagus.

PHYLUM.—Meaning literally "race" or "tribe," applied to the great groups into which the animal and plant kingdoms are divided.

PLATYHELMIA.—The flat-worms.

POLYMORPHIC.—Having many forms, e.g. the bees, queen, worker, and drone.

PORIFERA.—The organisms supplied with numerous pores or openings; sponges.

PROCTODÆUM.—The posterior region of the alimentary canal, lined by ectoderm.

PROGLOTTIS.—One of the segments of the tape-worm.

PROSOPYLE.—The " pore " or perforated cells in the Porifera.

PROTOPLASM.—Termed by Huxley " the physical basis of life," the substance of which all organisms are composed.

PROTOZOA.—Literally the " first animals." The phylum Protozoa includes the unicellular animals.

PSEUDOPODIUM.—A " false foot."

PSOCOPTERA.—The Order of Book-lice.

PUPA.—The phase in the life-history of an insect succeeding the actively feeding larva. To the onlooker it is a time of quiescence, but within the pupal case changes are taking place resulting in the breaking down of the larval tissues and the formation of those of the adult. Histolysis and histogenesis.

RHYNCHOTA.—The term applied to the Order including the bugs, so called because of the snout.

SALIVA.—The secretion formed by the salivary glands. Of great importance in many blood-sucking flies as it contains an anti-coagulating fluid.

SARCODINA.—Protozoons with naked bodies.

SCHIZOGONIC CYCLE.—Applied to the asexual phase in the life-history of certain animals; e.g. the malarial parasite, where the parasites multiply asexually in the blood of man by splitting or schizogony.

SCHIZONT or MEROCYTE.—The stage in the life-history of the malarial parasite developed from the trophozoite. The schizont splits up to give rise to the many merozoites.

SCOLEX.—The head of a tape-worm.

SIPHONAPTERA.—The fleas—the " sucking " insects " without wings."

SPECIES.—A collection of organisms which have been derived from a common ancestor and consequently resemble one another very closely.

SPIRACLE.—As used in this book in connection with the Insecta a spiracle is an opening into the breathing-tubes or tracheæ. The same term is also used for the first visceral cleft in the dog-fish and the blow-hole of a whale.

SPOROCYST.—The stage in the life-history of a Trematode that follows the miracidium. It is the first phase formed after the miracidium has entered the snail. Also applied to a phase in the Protozoa which precedes the liberation of sporozoite.

SPOROGONIC CYCLE.—The phases in the life-history of an organism, e.g. the malarial parasite resulting from the union of mega and microgamete.

SPOROZOA.—Protozoa which reproduce by the development of sporozoites.

SPOROZOITE.—The phase in the life-history of the malarial parasite that is found in the salivary glands of the mosquito. The sporozoites are liberated from the sporocyst.

STOMODÆUM.—The anterior portion of the alimentary canal, lined by ectoderm.

STROBILA.—The tape-worm stage of Tænia.

SYMBIOSIS.—The condition in which two or more organisms live together as "companions" or "partners," each benefiting from the association.

SYNCYTIUM.—The multinucleated, undifferentiated mass of protoplasm resulting from the disappearance of the cell-walls of certain cells, e.g. the syncytium of Ascaris formed from the epidermis.

THORAX.—Used here as applied to the Insecta as the term for the second division of the body lying between the head and the abdomen.

TRACHEAL TUBES.—The passages by means of which air is conveyed to all parts of the body of an insect.

TREMATODA.—The Class of worm which includes the liver-flukes. Derived from a word meaning "hole," "orifice." This was probably used as the suckers give the appearance of perforations.

TRIBLASTICA.—Organisms that are possessed of ectoderm, endoderm, and mesoderm.

TROPHOZOITE.—The phase in the life-history of the malarial parasite developed in the red blood-corpuscles of man from the incoming sporozoite.

TURBELLARIA.—The Class of free-living flat-worms. They are covered with rapidly moving cilia which have the effect of producing little whirlpools and so create a "bustle" or "stir."

UNIVOLTINE.—Applied to silkworms that produce only one brood in the year.

VIVIPAROUS.—Organisms that produce their young alive.

ZYGOTE.—The cell resulting from the union of the male and female gametes.

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